Beattie

FEB. 1963

POTOMAC RIVER BASIN REPORT

REPORT ON THE WATER
AND RELATED LAND RESOURCES

U. S. DEPARTMENT OF AGRICULTURE

REPORT ON THE WATER AND RELATED LAND RESOURCES IN THE POTOMAC RIVER BASIN

PREPARED BY

THE U. S. DEPARTMENT OF AGRICULTURE

CONTENTS

TABLES

FIGURES

REPORT ON THE WATER AND RELATED LAND RESOURCES IN THE POTOMAC RIVER BASIN
BY
THE U. S. DEPARTMENT OF AGRICULTURE

SUMMARY AND RECOMMENDATIONS

THE BASIN'S WATER PROBLEMS

The principal water resource problems in the Potomac River basin are: (1) floods, (2) stream pollution, (3) water supply, and (4) the demands for the recreational use of water.

The flood problem. Floods causing widespread damage occur on an average of once every 10 to 12 years within the Potomac River basin. The more recent floods of 1936, 1942, and 1949 caused extensive damages to agricultural areas, urban communities, and transportation and communication facilities.

Even more frequent flooding occurs in the upper tributaries throughout the basin. Although the rainfall is distributed rather uniformly throughout the year, summer rainfall is often characterized by intense thunderstorms that cause localized flooding. These frequent floods cause land damage from streambank erosion, damage to growing crops, infertile overwash, and flood plain scour. They also cause damage to minor agricultural improvements, secondary roads, bridges, homes, stores, and urban areas and industries. In addition, they create problems in maintaining stream channel capacity because of sediment deposition.

Because upper tributary damages are widely scattered, may occur infrequently at any one point, and seldom reach catastrophic proportions, data on their total effect are difficult to obtain. In the aggregate, however, they represent a significant economic loss.

The pollution problem. Pollution of the waters of the Potomac River and its tributaries has been a growing problem for nearly a century. Discharge of industrial waste became serious in the early 1900's, particularly in the areas of the North Branch and in the Shenandoah Valley. Acid waters draining from coal mines contributed to the deterioration of the water quality in western Maryland and West Virginia. Pollution from sediment began causing concern in the 1860's and became more serious with the destruction of forests on the watershed and the continuance of poor land use practices on the farmland. This problem was further aggravated by sediment contributions from real estate developments in the rapidly expanding urban areas.

The water supply problem. At present, water supplies in the basin are obtained generally from local springs or wells or small tributaries for the rural area needs and from deep wells or the larger streams for

the urban areas. The cities of Hagerstown, Maryland, and Shepherdstown, West Virginia, obtain their water from the main stem of the Potomac River. The Washington metropolitan area obtains most of its water from the Potomac. In addition, about 60 urban areas draw their water from the tributary streams. Natural flows have in the past been sufficient to supply the municipal and industrial needs in most areas. However, shortages are occurring in some localities. Projected population growth and industrial expansion, plus the projected development in agricultural and recreational activities in the basin, indicate that the available water resources in their present state of development cannot meet the future demand for relatively pure water.

Quantity and quality requirements for the recreational use of water. Demands for the recreational use of water for swimming, boating, fishing, hunting, and other water sports are growing and creating pressures from many groups. Simultaneously, usable resources for water-based recreation are diminishing in the face of the pollution situation and demands for increased supplies for municipal, industrial, and other uses.

THE REPORT

This report is based on a study of the water and related land resources in the Potomac River basin and presents that part of the comprehensive plan for the prevention or control of floods and the development and conservation of the water and related land resources with respect to present and future needs in the upstream portions of the basin.

The survey and investigations covered present rural land and water use and management in relation to the major water resource problems in the basin. They also considered past use and management as a basis for establishing trends leading to projections of necessary development programs from now to 2010.

Determination of overall water needs and an analysis of possible means of development and control for a comprehensive plan required a joint appraisal by contributing agencies. It included expected future municipal, industrial, agricultural, and recreational developments and water needs in the basin.

The Department of Agriculture developed information on: (1) trends in agricultural development and their relation to present and future water needs for agriculture, (2) erosion as it relates to the sediment and pollution problems, (3) local needs for water control and management in the upstream areas, and (4) the potential of upstream development for meeting these problems.

In addition, the Department of Agriculture developed information for the Corps of Engineers on past agricultural flood damages on the main stem and major tributaries and the impact of suggested major reservoirs on agriculture and other rural land use in the basin. This

information was considered by the Corps of Engineers in the formulation of a selected plan and alternatives for improvement of the main stem and major tributaries.

DESCRIPTION OF THE BASIN

Potomac River basin. The Potomac basin embraces an area of about 14,600 square miles. It includes the District of Columbia and parts of Maryland, West Virginia, Virginia, and Pennsylvania. It has a population of nearly 3 million people. The beauty of the streams, fields, and forests of the basin has made it a recreational area for increasing thousands of people.

The terrain of the basin varies from the flat Coastal Plains to the mountainous eastern slope of the Alleghenies. Between these extremes are the rolling country of the Piedmont Plateau, the Great Valley of the Shenandoah, and the Appalachian Highlands.

The soils of the basin range from the unconsolidated strata of sands, gravels, clays, and silts of the Coastal Plain to those derived from sandstone and shales typical of the eastern slope of the Allegheny Mountains. The soils of the Piedmont Plateau are derived from crystalline and sedimentary rocks and the soils of the Appalachian Valley are derived from limestone. Settlement and development of the basin proceeded in a large degree in relation to the physical characteristics imposed by the topography and soils of the respective regions.

The river has been used as a source of food, power, domestic and industrial water supply, and as a highway, a medium of recreation, a means of waste disposal, and as a defense barrier. As in other basins, the resources were freely used. The timber was harvested with little regard to future production. The land was farmed without regard to loss of soil by erosion or the sedimentation of streams. Coal was mined, and large quantities of mine acid were wasted into the streams. All these resulted in degrading the quality of the water for water supply, cooling purposes, and the marine life in the streams.

Early settlers found an abundance of land, water, and timber. Although there are numerous indications of much past mistreatment, these resources still make substantial contributions to the economy of the basin. However, they have the inherent potential necessary to make much greater contributions under intensified management and protection.

Basin population. For more than a century population has grown at a faster rate in the Washington metropolitan area than in the basin as a whole, but the growth became spectacular in the mid-thirties. Since 1900, the urban area has expanded from a closely built-up area of 7 square miles in Washington, D.C., and a smaller area in Alexandria, Virginia, to encompass more than 300 square miles at present. At the current rate, for example, more than 5 square miles of development are

added each year to the urbanized area of greater Washington.

The overall basin population increased from about 500,000 people in 1850 to almost 3 million in 1960. By 1985 it is expected to increase to almost 5 million. By 2010 it is expected to exceed 7 million. In 1910 the farm population in the basin had reached a peak of about 300,000. By 1950 it had declined to less than 278,000. It is expected to decline to about 200,000 by 1985 and to about 113,000 by 2010. Increases in the non-farm population of the open country areas are expected to more than offset the decline in farm population.

Since economic growth stems from attempts to satisfy human needs and wants, all resource uses may be considered to be related to population. Consequently, changes in land use in the Potomac River basin are closely related to the growth, distribution, and income characteristics of its population. Past trends in population and land use were used as basic data for developing projections of these trends into the future. The projections assume that the forces which produced our dynamic, expanding national economy will continue to exert a similar influence in the future.

<u>Present use and management of the land</u>. The treatment of the land usually is reflected in the quantity and quality of flows in the streams. The abuse of land or improper management of its cover in the headwaters of a watershed contribute to flash floods, accompanied by sediment deposition in channels and reservoirs and serious pollution of the water for downstream users. This points up the importance of a common interest between the users of land and the users of water.

Slightly less than 2 percent of the land in the Potomac River basin is without some degree of land use limitation. The remaining 98 percent is subject to some degree of permanent limitation in land use because of natural land characteristics. About half of this land is suitable for cultivation with the corrective measures needed to protect the land in this use. The remaining half should be permanently protected with a cover of grass, or trees and shrubs. The lack of proper farm and forest management practices has resulted in severe erosion problems on approximately 1,350,000 acres, or about 15 percent of the land surface of the basin. An additional 1,040,000 acres, or about 12 percent, have been subjected to moderate-to-severe erosion. Many additional acres of the lower slopes and flood plains are being damaged by deposition or infertile overwash as a result of the active erosion.

The most serious effects of erosion are the losses of topsoil and the depletion of the soil fertility. Both of these tend to reduce the ability of watershed land to produce adequate cover to help the soil to absorb and hold precipitation and reduce rapid runoff.

Without good cover the quality of stream water is also affected. Sediment interferes with the self-purification processes of a stream,

destroys fish and wildlife habitat, increases costs of purifying water supplies, and interferes with navigation by filling the channels with erosional debris.

More than three-fourths of the basin's forest area is making less than an adequate contribution to the protection of the watershed and reduction of rapid runoff. Similarly, many of the crops grown and most of the pasture cover are providing less watershed protection than could be attained and maintained under better farm management. In addition to low productivity, this lack of proper use and management results in increased flood runoff and in a reduction of the volume of ground water available as return flow to the streams during dry periods.

BASIN TRENDS

Trends in land use in the basin. Agriculture is the principal user of the land in the Potomac River basin. About 54 percent of the lands in the basin are in forest cover. Crop and pasture lands occupy 24 and 16 percent, respectively. There has been relatively little change in this ratio between forest and cleared land during the last several decades. Indications are that about 50 percent of the basin area will remain in forest cover over the next 50 years. However, two major forces are bringing about land use changes within the open land in the basin: (1) The former use is no longer profitable, and (2) higher economic returns are possible in some other use. These two forces have resulted in a decline in land in farms from about 7 million acres in 1900 to about 5.3 million acres in 1958. This acreage is expected to decline to less than 4.5 million acres by 1985, and to less than 4 million acres by 2010.

Trends in the basin economy. Despite an expected large decline in the crop and pasture land base by 2010, and a corresponding decline in farm population, farm production is expected to continue to increase throughout the 50-year period. The trend toward fewer but larger commercial farms; higher yields of crops and livestock; further specialization of production; and continued technological progress, including conservation farming, will contribute to a substantial rise in output and to the ability of farmers to achieve large increases in production with fewer inputs.

Basin farmers, along with all other farmers, will continue to be faced with the problem of balancing production to market demands. Recently, rapid technological progress in all phases of agricultural production has exceeded the growth in demand. This results in overproduction and relatively unfavorable economic conditions for agriculture as a whole and for small, inefficient units in particular. However, the economic outlook for basin farmers differs in at least two major respects. First, the Potomac River basin is contiguous to one of the great consumption and export markets of the world; and, second, most of the people in the basin are consumers rather than producers of

agricultural products. Farmers in the basin who have a sufficient quantity of high quality land and other resources can realize relatively high incomes from the production of milk, eggs, and other products desired in a "strictly fresh" condition. Presently, only a small minority of all farms within the basin are large commercial farms with highly productive land and high incomes. The percentage of these farms is expected to increase as the less efficient units move out of agriculture. However, some efficient, highly productive farms also will move out of agriculture in response to demand for space by urban and industrial interests. The amount and kinds of lands withdrawn will be a major factor in the future agricultural economy of the basin.

Future demands for water by rural users. During the next 50 years, the annual rural water requirements in the basin, excluding irrigation, are expected to increase 500 percent. This increase is attributed primarily to rising standards of living among rural people and increasing population in rural areas. The non-farm population in rural areas and small towns is expected to increase from 1,083,000 to 2,021,000 by 2010, while the farm population is expected to decline from 207,000 to 134,000. As a result, total annual rural water requirements, exclusive of irrigation water, are estimated to increase from 17 billion gallons to 100 billion gallons. Approximately 98 percent of the projected increase is attributed to increased population and increased per capita use. Annual livestock requirements are estimated to increase from 3.7 billion gallons to 5 billion gallons by 2010. Water required for orchard spraying and other agricultural uses is predicted to remain relatively constant at approximately 300 million gallons per year.

A part of the supplies necessary to meet projected requirements for rural uses will be provided by ground water sources as at present. To supplement the ground water it is expected that farm reservoirs will be developed to meet livestock and other agricultural needs. The needs of the rural communities and small towns will be provided for by larger withdrawals from surface streams or from storage in the upstream reservoirs.

Evaluation of future water needs for irrigation development in the Potomac River basin revealed that: (1) The location of the diversion could create localized shortages of water for competing users during periods of drought; (2) since the primary source of water for irrigation is from surface supplies, it could locally be in direct competition with such uses as municipal water supply and water quality control; (3) irrigation requires large amounts of water per acre; and (4) the peak demand for irrigation water usually occurs during July, which is also a peak demand period for residential and other non-farm uses, although record low flows of surface streams usually occur during August and September.

In spite of these possible problems, the projected irrigation requirements indicate little or no conflict with other water uses, because the irrigated areas are widely scattered and the total water required is

a relatively small percentage of the total basin requirements.

More than 400,000 acres of land physically suitable for irrigation lie within a reasonable distance of permanently flowing streams. It is estimated that during periods of severe drought approximately 25,000 acres of crop and pasture land will be irrigated by 1985, and approximately 40,000 acres by 2010. This represents an average annual increase of approximately 3 percent.

The volume of water estimated to meet the projected needs in 1985 is approximately 10,600 acre-feet for the peak month (July) and a seasonal total of approximately 35,200 acre-feet. For the year 2010, it will be approximately 17,200 acre-feet for the peak month, with a seasonal total of approximately 59,000 acre-feet.

RESULTS OF THE INVESTIGATION

The effects of land treatment. Changes in rural land use, together with some improvement in management and adequate protection against fire, are predicted to more than offset the unfavorable hydrologic aspects of the projected increases in urban development. These improvements in land use, cover conditions, and management will reduce peak flows and annual yields and increase low flows. The development of unit hydrographs indicated that the peak flows would be reduced in direct proportion to the reduction in runoff. The percentage of reduction of peak flows will vary with the amount and intensity of the rainfall, soil moisture conditions, and the season of the year.

With improvement in hydrologic conditions more of the precipitation from a given intensity storm will infiltrate into the soil. Indications are that approximately one-half of the additional infiltration will later find its way by lateral seepage and sub-surface channels into the stream channels to augment low flows.

As more water is infiltrated into the soil and more transpiration and deep percolation losses occur, there will be a tendency toward slight decreases in gaged annual yields. To provide an indication of the projected effects, percentage decreases in annual yields were calculated as one-fourth of the increase in low flows. Slight decreases in annual yields are indicated in all areas of the basin except the Coastal Plain.

Land treatment, as indicated by the National Inventory of Conservation Needs developed by the U. S. Department of Agriculture, will cause sediment yields to decline by 30 to 40 percent in rural areas located outside the Washington, D.C., area. However, future urban expansion around the Washington area can be expected to cause sediment yields of the same magnitude as at present, unless some control is invoked on the methods of land clearing, land grading, and street construction. High sediment yields will continue until full development is reached, and

only then will it decline to the normal low soil-loss rate for established urban areas.

Estimated needs have been computed for conservation treatment on expected acreages of cropland, pasture, woodland, and other lands for the year 1985. Available data indicate that at the present rate of progress it will take from 50 to 75 years to establish most of the needed conservation practices on agricultural and other lands of the basin and to develop the high level of management needed to bring about the improvements needed.

The land treatment measures will have to be supplemented with structural measures to bring about the improvements needed. The primary function of the upstream structural measures, in addition to storing water for water supply and quality improvement and recreation, will be to reduce peak flows and provide flood protection in the tributary watersheds of the basin.

<u>The plan for upstream structural measures</u>. Approximately 800 sites with topographic features suitable for the development of storage of at least 4 inches of runoff from the contributing drainage area were investigated. The cost of structures at these sites, singly or in various combinations, was studied in relation to the flood prevention and other benefits they would provide.

In a number of sub-watersheds the average low flows were not sufficient to meet the future water needs of the upstream areas. In these sub-watersheds structure sites were investigated that were suitable for providing supplemental flows either through the provision of additional capacity in floodwater retarding structures or as single purpose water supply structures. The amount of supplemental flows such structures would provide and the cost were estimated.

Structure sites within the boundaries of the National Forests were also investigated for recreational use. All potential structures were evaluated in relation to the recreational benefits they would provide based upon an estimated annual visitation computed for the site.

Water supply, water quality control, recreation, and flood prevention depend on the maintenance or regulation of streamflows and water surface areas. In many instances the requirement could be met best by multiple purpose structures. The additional streamflow required to serve estimated water supply needs often satisfied some of the water quality requirements. Where conditions warranted, the structures selected for a single purpose role also were analyzed as multiple purpose structures. Multiple purpose use, where justified, showed the greatest excess of benefits over cost and, therefore, was considered to be the most economical solution to the water resource problems.

In formulating the proposed plan for water resource development, consideration was given to all available means of fulfilling the existing or projected needs to the year 2010. The plan described in the report is considered to be the most practicable and economical means of supplying these needs. Each of the structures included in the plan was considered individually and in combination with various other proposed structures. In all cases the estimated average annual benefits of the combination of structures were equal to or exceeded the estimated average annual equivalent cost. The scheduled sequence of development is based on the requirements and needs over the 50-year period.

The plan includes a total of 418 structures to meet the needs of the upstream areas. These include 258 single purpose flood prevention structures, 73 single purpose water supply and quality control structures, nine single purpose recreation structures, and 78 multiple purpose structures. Of the 78 multiple purpose structures, 75 have flood prevention, water supply, and water quality control as their project purposes, and three have flood prevention and recreation as their project purposes.

Preliminary allocation of costs of the multiple purpose structures to the purposes of flood prevention, water supply, water quality control, and recreation were made by distributing the costs in proportion to the amount of storage provided for each use. No division of project costs was made between Federal and non-Federal interests. Benefits to each purpose were evaluated and the benefit-cost ratio for the proposed development was estimated.

The total first cost of the structures is estimated to be $104,754,900, with an estimated annual equivalent cost of $4,190,200. The average annual benefits are estimated to be $6,180,000. The benefit-cost ratio is 1.47:1.0.

CONCLUSIONS

1. The present use, conditions, and management of rural lands are largely responsible for:

   a. the production of food and fiber at a rate considerably below the potential of the land

   b. the present sediment problem and its contribution to stream pollution

   c. contributing in varying degrees to the flood and low flow problems, depending on specific locations and seasons.

2. Proper use and improved management of the land and water

resources are needed to help achieve a more stable streamflow of the quality necessary for maximum water utilization and to conserve and protect the productive capacity of the basin's soil resources. In the future, greater competition for land and water will require more intensive management of these resources.

3. The data contained in the National Inventory of Conservation Needs and the present rate of progress in establishing conservation measures make apparent an urgent need to accelerate the application of the measures.

4. To meet the present and future needs of the basin for the regulation of streamflow, to further alleviate floodwater and sediment damages, and to provide water storage and supplemental flow for various uses, the land treatment measures will need to be supplemented with structural measures.

5. To achieve the expected benefits from the plan for the development of the water and related land resource of the upstream watersheds will require Federal assistance in the installation of the recommended improvements.

RECOMMENDATIONS

It is recommended:

1. That the program for the Potomac River watershed authorized to be carried out by the Secretary of Agriculture by section 13 of the Flood Control Act of December 22, 1944, (58 Stat. 887), as heretofore or hereafter amended and supplemented, be authorized to be carried out by the Secretary of Agriculture throughout the entire Potomac River basin generally in accordance with that part of the comprehensive plan of improvements relating to upstream areas described herein with such modifications thereof as in the discretion of the Secretary of Agriculture may be advisable.

2. That in carrying out such program the Secretary of Agriculture be authorized to participate in the installation of works of improvement for water supply and water quality control generally to the same extent and under the same conditions as is provided for in the Water Supply Act of 1958, (72 Stat. 319), as amended, and the Federal Water Pollution Control Act, (62 Stat. 1155), as amended.

3. That in carrying out such program the Secretary of Agriculture be authorized to participate in the recreational development of upstream reservoirs for public use to the extent that he determines to be equitable in consideration of the assistance that is authorized for the same purpose under other Federal programs.

INTRODUCTION

AUTHORIZATION AND SCOPE OF THE COMPREHENSIVE PLAN

The Corps of Engineers has been authorized by two resolutions of the Senate Committee on Public Works to prepare a comprehensive plan for the control of floods and the development and conservation of water and related resources in the Potomac River basin.

The survey was initiated under the provisions contained in the resolution adopted January 26, 1956, by the Committee on Public Works of the United States Senate. The resolution called for the preparation of a comprehensive plan for control of floods and the development and conservation of the water and related resources of the basin, with emphasis on present and future needs for water supply and pollution abatement, fully coordinated with the Interstate Commission on the Potomac River Basin, and with the States of Maryland, Virginia, West Virginia, Pennsylvania, and the District of Columbia, and with the National Capital Regional Planning Council and other state agencies concerned to insure full consideration of all views and requirements.

The survey was completed under the provisions contained in the resolution adopted July 6, 1959, and amended April 27, 1960, by the Committee on Public Works of the United States Senate, which provided for the preparation of a plan for flood control, recreation, and development and conservation of municipal and industrial water supply and pollution abatement, fully coordinated with all agencies concerned.

The overall survey had three major objectives: (1) the determination of needs for water supply, water quality control, flood prevention, and recreation; (2) the evaluation of resource capabilities; and (3) the formulation of a plan for the development of water and related land resources.

So that the survey and report would fully reflect the many aspects of control and management of all the water resources in the basin, the Corps of Engineers requested the cooperation of the U. S. Department of Agriculture, and others, in the survey.

The Department of Agriculture participated in the survey under the provisions of section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, as amended) which authorizes the Secretary of Agriculture to cooperate with other Federal, state, and local agencies in surveys and investigations of the watersheds of rivers and other waterways to develop coordinated programs. The Soil Conservation Service, Forest Service, and Economic Research Service carried out the Department of Agriculture's part of the survey.

OBJECTIVES OF THE U. S. DEPARTMENT OF AGRICULTURE'S SURVEY

The purpose of the Department of Agriculture's participation in the survey was to: (1) examine the land use and management in relation to the water resource problems of the basin; (2) consider the local needs for water development in the upstream areas; and (3) evaluate the capabilities and potentials for meeting the needs, and to contribute to the formulation of a plan to satisfy the needs.

The Department of Agriculture developed information on: (1) trends in agricultural development and the future water needs for agriculture, (2) erosion as it relates to the sediment problem, and (3) needs for water control and management in small upstream watersheds and opportunities to meet these needs. This information was integrated with information developed by other agencies in formulation of a plan for development of the basin.

In addition, the Department of Agriculture developed information on the agricultural flood damages on the main stem and major tributaries, and the economic impact of the major reservoirs on agriculture and other rural lands in the basin. This information was provided to the Corps of Engineers for use in the formulation of a plan and alternatives for improvement of the main stem and major tributaries.

SECTION I - PROJECTIONS AND SOURCES OF DATA

1. POPULATION AND RELATED USE PROJECTIONS

Changes in land use in the Potomac River basin are closely related to the growth, distribution, and income characteristics of its population and that of surrounding areas.

Population projections for the Potomac River basin were developed by the U. S. Department of Commerce, Office of Business Economics, for the major study areas within the basin as shown in figure 1. These data indicate that the projected growth of the Potomac River basin economy over the next half century will come partly from population expansion. For the past three decades, the basin's population has grown faster than that of the Nation. Indications are that it will continue to grow somewhat faster than that of the Nation over the next 50 years. This growth will be general throughout the basin, but varying in degree in the sub-regions. However, indications are that most of the more than 4 million additional persons will very likely be concentrated in the Washington metropolitan area.

The projected future economic growth is expected to result in increasingly greater demands on the land and water resources of the basin. Outdoor recreation will continue to increase, requiring more land and water space. The agricultural use and management of the land will affect both the quality and quantity of streamflow. It was assumed also that Federal and state assistance programs will continue at least at their present level. Therefore, watershed management, including land treatment and structural works of improvement, will be essential elements in a program of improved use and control of the resources of the basin.

2. IMPROVED TECHNOLOGY AND FUTURE LEVELS OF MANAGEMENT

Agriculture is experiencing a technological revolution. Recent changes in production per man-hour and the increasing substitution of capital for labor serve as an indicator of this impact. Production per man-hour has increased 81 percent in the last 10 years, or about 9 percent per year. 1/ This compares with an increase of only 2.5 percent per year in non-farm industries. These changes are rapidly transforming agriculture into one of the higher capital-using industries.

Potomac River basin farmers, along with all others, will continue to be faced with the problem of balancing production to market outlets.

1/ "Changes in Farm Production Efficiency", U. S. Department of Agriculture Statistical Bulletin No. 233, Revised September 1959.

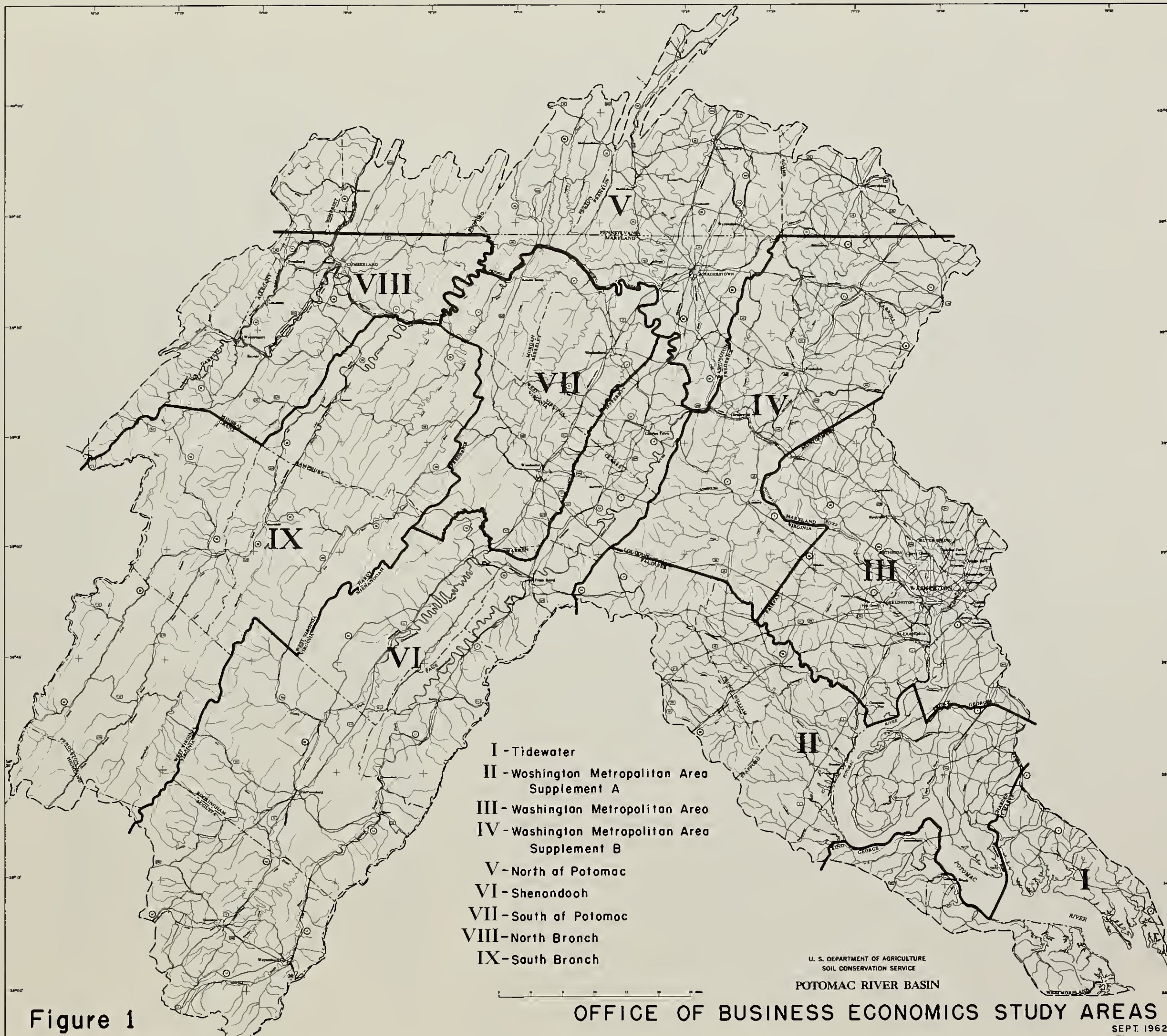


Figure 1

OFFICE OF BUSINESS ECONOMICS STUDY AREAS

Recently, rapid technological progress in all phases of agricultural production has exceeded the growth in demand. These trends result in overproduction and relatively unfavorable economic conditions for agriculture as a whole and for small, inefficient units in particular.

With most of the basin projections tied to an assumption of continued high rate of economic growth, the number of low-income farms in the basin will decrease. In relative terms, low-income farms probably will always be a part of the agricultural scene. However, as new technology makes possible the utilization of their farm resources with less labor input, low-income farmers will adjust either by acquiring more resources or by seeking part-time work off the farm.

3. PHYSIOGRAPHIC REGIONS AND SUB-AREAS

Variations in agricultural characteristics within the Potomac River basin are related to differences among the physiographic regions in the basin. Therefore, data were summarized and evaluated by the physiographic regions and sub-areas within the basin rather than by states and counties.

Figure 2 is a map of the basin showing the five major physiographic regions.

Twelve sub-areas within the physiographic regions were delineated as the common level to which all applicable agricultural data relative to project formulation were summarized and evaluated. These sub-areas were generally comparable to the economic area breakdown used by the Office of Business Economics, U. S. Department of Commerce. They provide data generally applicable to the additive evaluation approach from stream source to the mouth. This evaluation approach was used by the Corps of Engineers, wherein the flows were computed and water use was subtracted and in-flows added progressively downstream. Figure 3 is a map showing the 12 sub-areas.

Data of a background nature, such as the early settlement and subsequent growth, general climate and topographic data, and similar broad-scope statements were prepared by physiographic regions. Other data which were available at finer levels of breakdown, such as sub-watersheds or stream reaches, are discussed at both the sub-area level and the lower level wherever this was desirable.

4. ADAPTATION OF THE CONSERVATION NEEDS INVENTORY TO THE POTOMAC RIVER BASIN

Historical and projected trends of land use changes were needed for planning purposes in the Potomac River basin survey. A special summary of the Conservation Needs Inventory based on approximately 1,800 100-acre sample plots, which represented a 2 percent random sample of the total basin area, was selected for use. These data provided land use information and other land conditions for 1958, summarized by physiographic

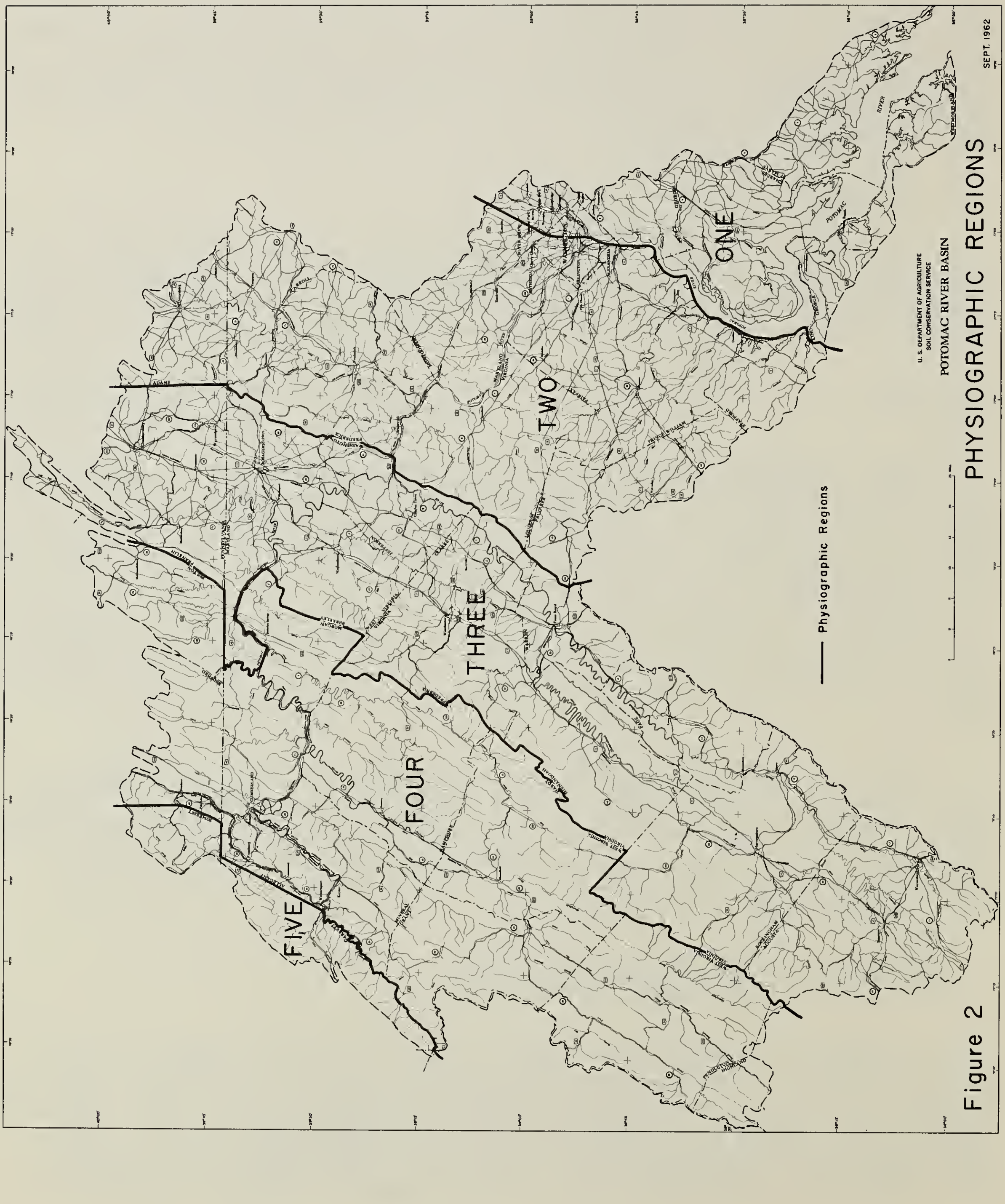

PHYSIOGRAPHIC REGIONS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
POTOMAC RIVER BASIN
SEPT. 1962
Physiographic Regions
ONE
TWO
THREE
FOUR
FIVE

Figure 2

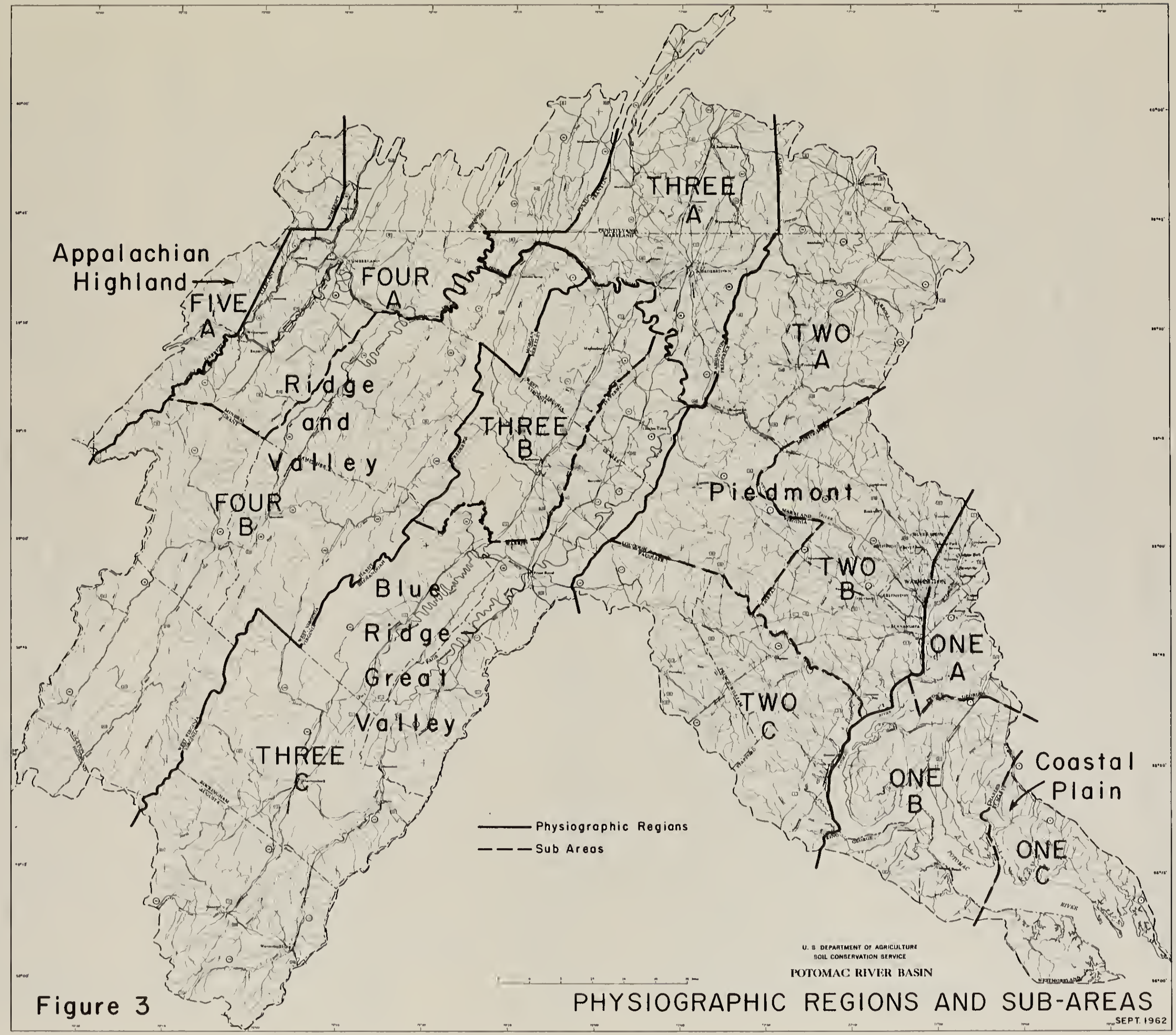


Figure 3 PHYSIOGRAPHIC REGIONS AND SUB-AREAS

regions, sub-areas, land resource areas, and land use capability classes. Total acreage estimates by land use, soil type, slope, erosion, and land capability were tabulated. These data provided all cooperating agencies with the same land base figures, thus insuring uniformity of results among selected phases of the study.

5. DELINEATION OF SUB-WATERSHEDS WITHIN THE POTOMAC RIVER BASIN

To insure adequate coverage of localized water resource problems the basin was divided into 77 sub-watersheds as shown in figure 4. The drainage area of the sub-watersheds ranged from about 50 to several hundred square miles. For the most part, the sub-watershed boundaries conform to the boundaries of the sub-areas and the physiographic regions. Each sub-watershed was analyzed for water supply needs for the upstream area, flood prevention potentials, and impoundment possibilities. These data were used in project formulation.

The sub-watershed approach made possible the evaluation of flow characteristics and associated physical, engineering, and economic data for the basin at the local level and, also, in an additive manner for the higher levels of sub-areas and physiographic regions. The water development formulation procedure was arrived at in an additive manner from the sources of streams to their mouths. Thus, these data were meaningful in arriving at the overall needs of the basin.

The delineation of the sub-watersheds also conform to the division of that portion of the Potomac River basin which is authorized for improvement by the Flood Control Act of 1944, as amended and supplemented.

6. USE OF DATA FROM SAMPLE WATERSHEDS

Time and resources did not permit a detailed hydrologic and hydraulic analysis of each sub-watershed of the basin. Existing watershed work plans representative of each physiographic region were used to approximate reduction of flood damages in relation to the control of the drainage area and other factors used in the evaluation of upstream structural measures. A factoring system was developed from the detailed computations in existing work plans for the respective physiographic regions. These factors were used to estimate the benefits which would be provided by the proposed structures by reducing damages and producing benefits.

A general reconnaissance survey was made of each sub-watershed to classify flood plain land by damage reaches. Data were recorded on: (1) flooding, (2) low flows, (3) erosion and sediment problems, and (4) potential for more intensive development. A separate economic analysis was carried out for each sub-watershed. This took into account the present cropping pattern or present use of the flood plain


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
POTOMAC RIVER BASIN
SUB-WATERSHEDS
SEPT. 1962
LEGEND
Physiography Boundary
Sub-Watershed Boundary
Sub-Watershed Number
81.0 Sub-Watershed Area (Square Miles)

Figure 4

acres. Projections were made of the cropping pattern yields and costs with flood protection. The net income for a composite acre based on present and projected use under protection and good management conditions was computed. Damages to businesses, residential property, bridges, roads, and minor fixed improvements were determined in order to compute the average annual damage for the reach or reaches. These damages were summarized by sub-watersheds, but they were also identified by reaches to be used directly in the economic evaluation of alternative combinations of structures. Other project purposes were included in accordance with the local needs.

7. USE OF DATA FROM SAMPLE AREAS

Because of the magnitude of the job it was necessary to use sample areas to determine: (1) present and future hydrologic conditions, (2) rate of erosion and sediment production, and (3) trends in changes in land use. Data were summarized by cropland, pasture, woodland, and other uses to arrive at the overall soil-cover complex indices for the physiographic regions. To obtain the amount of sediment production from sheet erosion for various physical areas, the average annual soil loss per acre was computed for a homogeneous parcel of land or land resource unit which had similar soil types, land use, geological influence, and slope and erosion characteristics. The land resource unit was considered to be an appropriate unit for a sheet erosion study because the Conservation Needs Inventory listed the estimated acreages for each land use in each land resource unit by soil, slope, and erosion combinations. From these data the sheet erosion estimates were developed.

Geomorphological studies of the area indicate that streams of the same order have similar physical characteristics if the areas have the same type of geological structure, climate, and lithology. It was concluded that erosion damage to bottom land associated with the particular stream order would be of approximately the same magnitude anywhere within the same physiographic region. A large number of bottom land sediment and erosion damage ranges were run on the various tributaries and the main stem of the Potomac. These were tabulated to obtain the average range or cross section of bottom land per stream order found in each physiographic region of the basin. The ranges were averaged and converted to the area damaged in acres.

An airphoto analysis was made to determine past trends in land use. Trends for two consecutive time periods, 1938-52 and 1952-58, were based on different flights and summarized by physiographic regions and subareas. By comparing before and after conditions, land use changes were measured for the time interval between photographic flights for the individual plots. Applying an expansion factor to the changes measured resulted in an estimate of changes that occurred within the various physiographic regions and sub-areas in the basin.

SECTION II - THE POTOMAC RIVER BASIN

8. GENERAL

The Potomac River basin embraces an area of about 14,600 square miles. It includes the District of Columbia and parts of Maryland, West Virginia, Virginia, and Pennsylvania, and has a population of nearly 3 million people. The beauty of the streams, fields, and forests of the basin have made it a recreation ground for increasing thousands of people. The Potomac River supplies a major part of the water for the National Capital area and municipalities and industry throughout the basin.

The accumulation of knowledge about the Potomac River, its behavior, and relation to the land, began early in American colonial times. Washington's diaries contain many entries relative to the river basin, its forests, soils, and topography. As in other basins, the resources were freely used. The timber was harvested without much regard to future production. The land was farmed without regard to loss of soil by erosion and sedimentation of streams. Coal was mined without regard to the large quantities of mine acid wasted into the streams which resulted in degrading the quality of the water for water supply, cooling purposes, and fish and wildlife.

Although there are numerous indications of much past mistreatment, the land, water, and timber resources still make substantial contributions to the economy of the basin. They have the inherent potential necessary to make much greater contributions if given intensified management and protection.

9. DESCRIPTION AND AGRICULTURAL USE OF THE BASIN BY PHYSIOGRAPHIC REGIONS

The Potomac River basin lies within a portion of the Atlantic slope drainage basin extending from the Allegheny Mountains to the Chesapeake Bay. The terrain of the basin varies from the flat Coastal Plains to the mountainous eastern slope of the Alleghenies. Between these extremes are the rolling country of the Piedmont Plateau, the Appalachian Valley, and the Appalachian Highlands.

The soils of the basin range from the unconsolidated strata of sands, gravels, clays, and silts of the Coastal Plain to those derived from sandstone and shales of the middle to early Paleozoic Age that have been folded and faulted into long parallel ridges, typical of the eastern slope of the Allegheny Mountains. The soils of the Piedmont Plateau are derived from the crystalline and sedimentary rocks, and the soils of the Appalachian Valley are derived from limestone.

Settlement and development of the Potomac River basin proceeded

in a large degree in relation to the physical characteristics imposed by the topography and soils of the respective regions.

Physiographic Region One - Coastal Plain

Settlement began in the Coastal Plain region soon after initial exploration by Captain John Smith in 1608. Early development was agriculturally oriented. The generally deep soils occurring on the broad, flat uplands provided a favorable environment for farm crops. By 1650 tobacco growing had become the major economic activity of the region. During this early era tobacco was grown as a continuous crop without benefit of fertilizer or winter cover crops. Consequently, the combined effect of erosion and declining soil fertility soon became evident. A period of economic decline hit the area as tobacco prices fell off about the end of the 18th century. Also prosperous ports were being destroyed by sediment deposits in the channels and harbors. These factors combined to cause a migration inland and much of the abandoned land reverted to forest, often pure stands of pine. These past events, plus the more recent rapid expansion of urban areas, have resulted in the present low percentage of land under cultivation.

Presently, only 23 percent of the land is being cultivated and approximately 61 percent is forested. While a drowned coastline and swamping of the upper flood plains, due to sediment impaired drainageways, has restricted bottom land use to either forest cover or idle swampy lands, present competition for land for farming is such that some high capability farmland remains in forest. The forests are about evenly divided between hardwood stands, with oak predominating, and softwood stands composed of the southern yellow pines. The present average stocking is approximately 3,000 board feet per acre. The average annual cut of about 60 board feet per acre is the highest in the Potomac River basin, but represents only about one-fifth of the potential production rate attainable under a medium level of management.

This region has the mildest climate of the basin with a growing season in excess of 200 days and an average annual rainfall of about 42 inches.

Physiographic Region Two - Piedmont

Settlement and development in the Piedmont region began at the time agriculture in the Coastal Plain had reached its climax. Agricultural production from this region continued to dominate the economy of the Potomac River basin for more than 100 years. Although tobacco was important at first, it was grown in combination with other less demanding crops as far as soil fertility was concerned. Wheat quickly became the major crop. Livestock enterprises also became increasingly important as a result of the demand for meat and other livestock products by an increasing population.

The Piedmont region lies between the fall line and the crest of the Blue Ridge Mountains. It is composed of three geologic units, two of which are composed of crystalline or metamorphic rocks and form a hilly-to-mountainous topography. Soils formed from these rocks are variable in physical characteristics depending on their parent material. They are equally variable in fertility. The third unit is the flat, plain-like lowlands underlain by sedimentary rocks of the Triassic Age.

Because of the variety of soils and topography, land use is divided about equally between livestock and forest production. A large portion of the cultivated land is used to support the livestock enterprises.

Approximately 40 percent of the Piedmont region is in forest cover. Much of this area is in the foothills of the Blue Ridge Mountains and generally occupies the steep slopes and thin, less fertile soils. The timber stands are primarily hardwoods, mainly oaks, but with a scattering of yellow poplar and associated species on the more favorable sites. The average stocking is approximately 2,500 board feet per acre with an average annual cut of about 50 board feet per acre. This level of stocking and production is substantially below the potential for the area.

Use of forest land was similar to that of the Coastal Plain. Early cutting of forests was done primarily to clear land for farming and to supply local needs for lumber. Introduction of livestock raising resulted in the clearing of additional land for meadows and pastures. Heavy cuts to provide timber products were not made until the beginning of the logging boom during the late 1800's. Many of the cutover areas also were burned several times. In recent years improved fire protection has permitted natural restocking, although often with less desirable species that produce smaller volumes and lower grade products.

The Piedmont region has a climate which can support general farm crops with a growing season of about 186 days and an average annual rainfall of about 40 inches. Urbanization is rapidly making inroads into the agricultural sectors of the Washington metropolitan area, but at present industrial development remains small.

The city of Washington, D.C., is located along the fall line between the Piedmont and the Coastal Plain regions. The expansion of the Washington area to accommodate a growing population has increased the competition for land. High capability land formerly used for agricultural purposes has been taken for urban and some industrial use.

Physiographic Region Three - Appalachian Valley

West of the crest of the Blue Ridge Mountains lies the Appalachian

Valley or, as it is sometimes called, "The Great Valley." Settlement in the Appalachian Valley began about 1730, primarily by farmers of German and Scotch ancestry who moved down the valley from earlier settlements in Pennsylvania. Agricultural lands were fairly well settled by 1800. The broad, limestone-based valleys of the Shenandoah River and the Conococheague and Antietam Creeks were especially adapted to the livestock-wheat type of farming the settlers brought with them. The farms on the lower slopes of the western side of the Blue Ridge and in the "Great Valley" beyond began to prosper as the tidewater plantations declined.

Pig iron produced in furnaces along the North and South Forks of the Shenandoah was the basis for early forest exploitation. Wood was converted to charcoal and used to smelt the ore mined from shallow pits throughout the area. As a result, the forests around these furnaces were subjected to yearly "coaling" for a period of about 30 years.

The war between the states brought marked changes in the region. Many of the major battles were fought here and farm property damage was high. Forced to rebuild much of its agricultural industry following the conflict, this region lost its supremacy in wheat production to the mid-West. This resulted in an eventual strengthening of livestock production and the development of the fruit industry. More recently, dairying has become increasingly important, and poultry is also now a major enterprise in some parts of the region.

Iron production declined after the war and the forests began to be put to other uses. From 1865 to 1900 many tanneries were built in the region to make use of the plentiful supplies of tannic acid in the nearby stands of chestnut and chestnut oak. Occurrence of the chestnut blight, between 1910 and 1925, killed the entire stand of chestnut which formerly made up 30 to 40 percent of the forests on the drier sites. This was largely responsible for the decline of the tanning industry.

Very severe cutting for charcoal and chemical wood, often followed by frequent fires, plus general removal of trees for sawtimber, resulted in replacement of former forest species with extensive low grade stands and a general exodus of the wood-using industries from the area.

Greatly improved fire protection and acquisition of about one-third of the forest area for National Forest and National Park purposes have resulted in a gradual improvement of the forests of the region in recent years. Many of them are now again reaching a productive condition and a rebirth of wood-using industries can be expected.

Land located on moderate slopes is intensively used. Cultivated crops make up about half of the land use. The land formerly cropped has not been intensively used for several decades, but demand for recreational use and summer home sites has developed recently. Some areas are being developed for industry.

At present about 50 percent of the region is in forest cover. The forests are mainly located on the steep slopes of the Blue Ridge and Allegheny Mountains and the sandstone and shale soils in the Massanutten Mountain area. The stand is primarily hardwoods, largely composed of mixed oak species. However, small acreages of pitch and Virginia pine occur on the poorer sites and yellow poplar and associated species in the coves.

The average stocking of 1,800 board feet per acre is very low from the standpoint of timber production and provides insufficient cover for good watershed protection. The average annual cut of 40 board feet per acre is far below the potential of these sites, but still is in excess of the amount that should be taken to properly restore these stands to optimum production conditions. Of the total forest area of the region, nearly one-third is now in public ownership and is being managed to return it to original production and protective qualities.

The growing season of 171 days and an average annual rainfall of about 37 inches is well suited to the general and grassland type of farming that is predominant in the region in support of the livestock and dairy industry.

Water resources in the region are variable, with some areas possessing good ground water resources, while other areas are limited in supply. Generally, the underlying rock strata of the valley are not as good aquifers as those of the Coastal Plain and Piedmont. Throughout the region generally, despite the occasional large yield developments such as Du Pont Basic City wells and the Merck wells, ground water will provide supplies only for rural domestic demands.

Within the region are located several of the largest upstream urban areas in the basin, including Hagerstown, Maryland; Chambersburg, Pennsylvania; Charles Town, West Virginia; and Winchester, Harrisonburg, Staunton, and Waynesboro, Virginia.

Physiographic Region Four - Appalachian Ridges

A multiple pattern of settlement developed in the Appalachian Ridges region. This area was first settled about 1740 by industrially-minded English emigrants. The settlements were founded along major streams. Shortly thereafter other groups of settlers, during their migration to the West, stopped off and established livestock farms on the highlands of the region. Large areas were cleared for pasture and some steep mountain land was utilized for cultivated crops. Animal husbandry quickly became a major farm enterprise. The acreage of cultivated crops increased. Due to the unstable nature of these mountain soils derived predominately from sandstone and shales, erosion was severe and soil losses were high. Consequently, much of the cleared land was abandoned. Abandonment of farms began on the highlands even before a large acreage of the bottom lands had been brought under cultivation.

Farming in the broader flood plain valleys in the region developed along a more substantial pattern. These farms are similar to those in the "Great Valley." In recent years they have increased in size, been adapted to modern technology, and continue as prosperous farm businesses.

For the region as a whole, however, non-farm industries dominate the economy. Less than 30 percent of the land originally cleared for farming is still in this use. Farming has given way to forestry or other uses on the hill land. Industry competes for limited available space in the valleys.

As in the Appalachian Valley region, most of the forest exploitation came about as a result of the industrialization of the region. Wood was used for charcoal in firing the blast furnaces. Large quantities of chestnut and chestnut oak were cut to provide raw materials used in the tanning industry. Construction of a pulp and paper mill in the North Branch valley provided a local market for large quantities of raw materials. Other pulp mills located adjacent to the area also drew heavily on the forest stands of the region. Many of the stands were clear-cut for pulp and other products and then burned over. These combined factors created many of the low quality second growth stands which characterize the region today. Approximately 75 percent of the region now is in forest, composed primarily of hardwood species. The oaks predominate with inter-mixtures of northern hardwoods at the higher elevations, pitch and Virginia pine on the poorer sites, and yellow poplar and associated species in the coves and on the bottom lands. Present average stocking of 1,440 board feet per acre and an average annual cut of 40 board feet per acre are far below the potential for the region. The appreciably improved conditions now found as the result of improved protection and management on approximately 290,000 acres of public forest land is indicative of the capability of the region.

The climate of the Appalachian Ridges is somewhat cooler than that of the Appalachian Valley. The growing season is limited to about 150 days. The average frost-free period extends from around the first of May to the early part of October. The average annual precipitation, which includes a considerable amount of snow, is about 35 inches. Rainfall, however, varies considerably in small areas due to topographic influences. Generally, about 55 percent of the total precipitation occurs as rainfall during the growing season.

Physiographic Region Five - Appalachian Plateau

The Appalachian Plateau region was the last of the regions in the basin to be developed. It is an upland of more than 3,000 feet in elevation. It is the westernmost portion of the basin and also the headwaters of the Potomac River. This region has been severely dissected by narrow drainageways to form deep, steep tributary valleys with little or no flood plain.

When the land was first opened to settlement a hardy race of Scotch-Irish-English immigrants came to the area. Many of them were heading further west where there was better land, but some families stopped here and built homes. Many of the highland ridges were cleared and farmed, although the land was steep and subject to erosion. The type of farming which the settlers introduced to the area did not lend itself to mechanization. Expansion was further hampered by the lack of large markets and inadequate local transportation routes.

The area was originally settled in small tracts. The farms that remain are small, with more than 40 percent of them under 30 acres. Outside sources of capital are limited. Some employment opportunities were available in the coal industries, but most subsidiary industries developed in the Ohio Valley to the west and in the North Branch of the Potomac Valley to the east. As time went on, more and more of the younger people left the farms and moved to job opportunties in the industrial areas. This was accelerated during the World War II years and has continued. No new activity has come in to fill the vacuum left by a declining agriculture.

The cropland of the Appalachian Plateau is limited. Crop and pasture together amount to slightly more than 14 percent of the total land use. About 25 percent is in "other" uses. Future land use projections indicate a continuously declining farm acreage. Present cropland use is devoted chiefly to hay and oats to support dairy or other livestock enterprises. Approximately 61 percent of the region is now in forest cover. The present forest area is composed of formerly farmed areas and lands that have always been in forest cover but which have been subjected to poor management. The stand is primarily oaks on the lower elevations, with a substantial mixture of northern hardwoods and hemlock and spruce on the higher elevations.

Although the acreage of forest land is relatively small compared with the other regions, its important location in the headwater area of tributary streams makes its present poor stocking and condition a major contributor to local stream flow problems.

Extensive strip coal mining has left many surface scars on the landscape. This has resulted in increased sediment yields and contributed to the local pollution problems.

The Appalachian Plateau has the coolest climate of the basin, primarily because of its altitude. January average temperatures are about 29°F., and July average temperatures are only 69°F. The growing season for the region is about 127 days. The frost-free period generally extends from about May 21 to late September.

The average annual precipitation, which includes 45 to 70 inches of snow, amounts to about 45 inches. Generally, about 40 percent of

the precipitation occurs as rainfall during the growing season. Runoff for the region is the highest in percentage of precipitation of any region in the basin. The average annual runoff is about 20 inches.

10. TRENDS IN POPULATION GROWTH

The overall basin population increased from about 500,000 people in 1850 to almost 3 million in 1960. By 1985 it is expected to increase to almost 5 million. By 2010 it is expected to exceed 7 million. In 1910 the farm population in the basin had reached a peak of about 300,000. By 1950 it had declined to less than 278,000. It is expected to decline to about 200,000 by 1985 and to about 113,000 by 2010. Increases in the non-farm population of the open-country areas are expected to more than offset the decline in farm population.

For more than a century population has grown faster in the Washington metropolitan area than in the basin as a whole, but the growth became spectacular in the mid-thirties. At the current rate more than 5 square miles of developed area are added each year to the urbanized area of greater Washington. Since 1900, the urban area has expanded from a closely built-up area of about 7 square miles in Washington, D.C., and a smaller area in the old city of Alexandria, Virginia, to encompass more than 300 square miles at present.

11. TRENDS AND PROJECTIONS IN LAND USE AND MANAGEMENT

Two major forces are bringing about land use changes in the basin: (1) The former use is no longer profitable, and (2) higher economic returns are possible in some other use. These two factors have resulted in a decline in land in farms from about 7 million acres in 1900 to about 5.3 million acres in 1958. This acreage is expected to decline to less than 4.5 million acres by 1985 and to less than 4 million acres by 2010.

The acreage of combined crop and pasture lands has been declining since about 1900. "Forest" and "all other uses combined" increased during the 1900-58 period. From 1960 to 2010, however, woodland is expected to join crop and pasture land as a slowly declining segment of major land use. Cropland is expected to decline from about 23.4 percent of total land area in 1958 to 18.2 percent in 1985 and 13.2 percent in 2010. The acreage of pasture is expected to decline from 16.5 percent of all land in 1958 to 15.2 percent in 1985 and to 13.3 percent in 2010. Woodland is expected to decline slightly from 54.5 percent in 1958 to 53.9 percent in 1985 and to 50.9 percent in 2010. All other uses combined, (mainly urban, idle, and recreational use) made up 5.6 percent of the total land area in 1958. This category is expected to increase to 12.7 percent of all land by 1985 and to 22.6 percent by 2010. Figure 5 shows the projected changes in land use from 1958 to 2010. Despite an expected large decline in the agricultural land base to 2010, along with a

PROJECTED CHANGES IN LAND USE

From 1958 to 2010

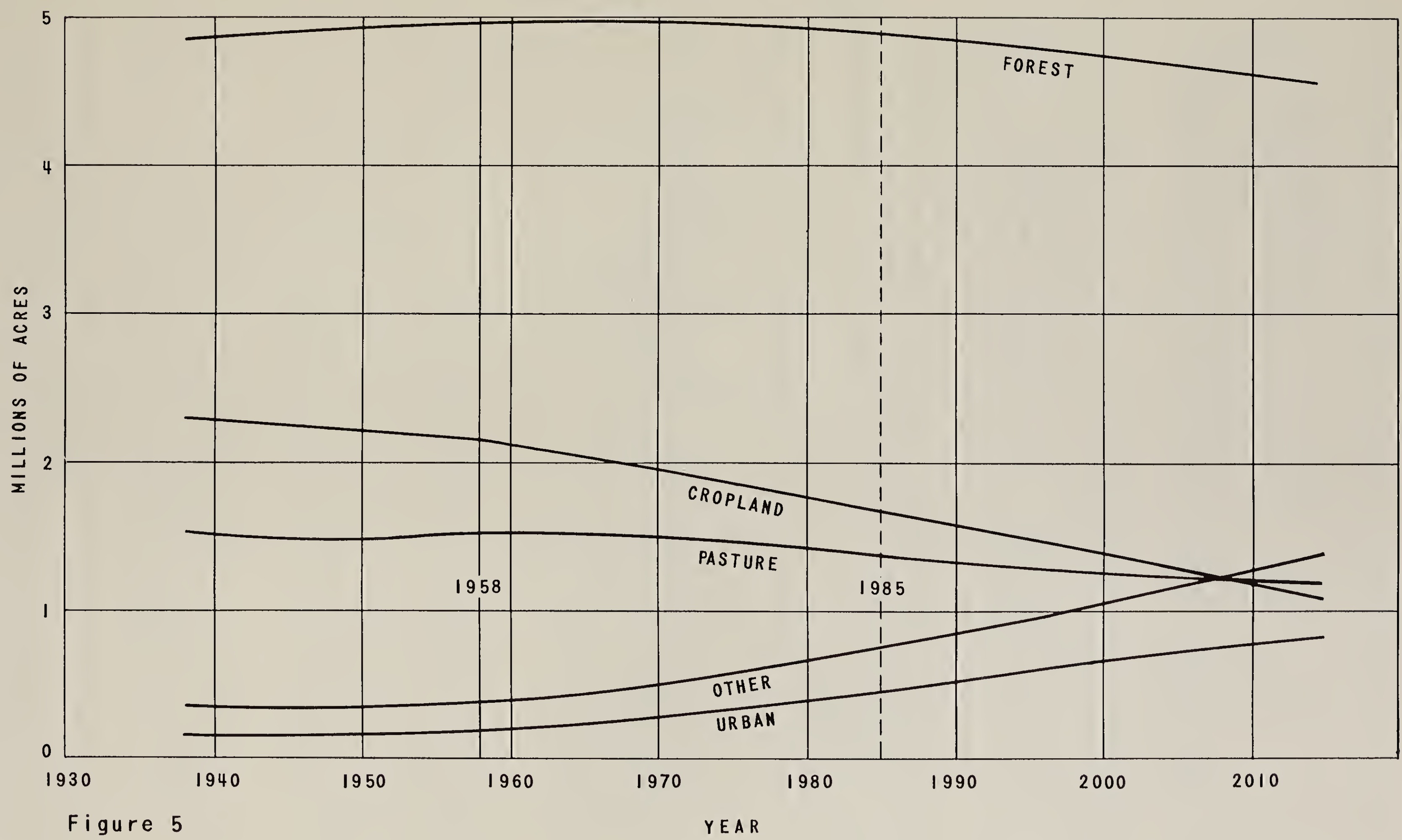


Figure 5

corresponding decline in farm population, agricultural production is expected to continue to increase throughout the 50-year period. The trend toward fewer but larger commercial farms, higher yields of crops and livestock, further specialization of production and continued technological progress, including conservation farming, will contribute to a substantial rise in output per man-hour and to the ability of farmers as a group to achieve large increases in production with fewer inputs of farm labor and less costly maintenance of the land productivity.

Various Federal, state, and local agencies are generally administering the 972,700 acres of publicly-owned forest land in accordance with sound management principles, and continued progress toward optimum production is expected. Past and present activities under the authorized Federal flood prevention program in the Potomac River basin and other state and Federal programs in the basin have resulted in forest fire protection and suppression organizations and programs generally adequate to meet normal conditions. Some of the forest landowners, particularly the industrial owners, have realized the importance of increased productivity from their lands and have initiated management programs.

However, over 3 million acres of forest land, owned by nearly 64,000 individuals, is in generally "poor" condition and little progress toward improved management is evident. The present rate of progress is inadequate to meet either the current situation or the still more critical one that will exist if the projected demands for water and other forest uses and products materialize.

SECTION III - THE WATER RESOURCE PROBLEMS OF THE BASIN

12. PROBLEMS RELATED TO HIGH AND LOW FLOWS

Damaging floods have occurred on an average of once every 10 to 12 years within the Potomac River basin. The more recent major floods of 1936, 1942, and 1949 caused widespread damages to agricultural areas, urban communities, and transportation and communication facilities. Agricultural areas subject to flood damage are widely distributed and generally lie in narrow strips along the streams. The limited acreage of the bottom land and its natural fertility have resulted in intensive agricultural development in some areas. Changes in land use from forests or grass to crops on these fertile bottom lands have increased erosion and scour.

Encroachment on the flood plain by industry and urban development has resulted in an increase in the flood damages. In the mountain areas the narrow valleys restrict available space for urban growth, and the tendency to occupy the flood plains during prolonged periods between inundations has occasioned costly damages during floods and rendered expensive and difficult the construction of adequate flood prevention structures.

The 1936 and 1942 floods combined caused extensive damages to urban communities and agricultural areas. Heavy cloudbursts in 1949 over the mountains in the vicinity of Bridgewater, Virginia, and Petersburg, West Virginia, amounted to about 12 inches of rainfall in 24 hours and caused considerable damage to this area. This storm resulted in the loss of 11 lives and damages estimated at over $9 million. The damages were mainly from local floods and tremendous mountain slides.

Frequent flooding occurs in the upper tributaries throughout the basin. Although the rainfall is distributed rather uniformly throughout the year, summer rainfall is frequently characterized by intense scattered thunderstorms that cause localized flooding. These frequent floods cause damage to growing crops; land damage from streambank erosion, infertile overwash, and flood plain scour; damage to minor agricultural improvements, secondary roads, bridges, homes, and stores; and create problems in maintaining stream channel capacity.

Because upper tributary damages are widely scattered, occur infrequently at any one point, and seldom reach catastrophic proportions, data on their total effect are very difficult to obtain. However, in the aggregate, they represent a significant economic loss.

The shape and character of the basin are such that they favor rapid runoff with high flood waters for short periods of time. Due to the pattern of the streams in the basin, tributaries of nearly equal length converge at several points to synchronize flood crests. Consequently, larger

flood flows occur in the Potomac than the same amount of flood runoff would produce in some of the adjacent coastal rivers.

Within the basin there is often a case of either too much or too little water. The lack of reservoirs to store some of the water from the maximum flows, for release during periods of drought, contributes greatly to the supply deficiencies. These deficiencies involve not only the quantity of water available for use but also the quality of water.

13. THE WATER SUPPLY PROBLEM

At present, water supplies in the basin are obtained generally from local springs or wells for the rural area needs and from deep wells or the larger streams for the urban areas. The cities of Hagerstown, Maryland, and Shepherdstown, West Virginia, and much of the Washington, D.C., metropolitan area obtain their water from the Potomac River. In addition, about 60 communities draw their water from the tributary streams. The natural flows have been sufficient to supply the municipal and industrial needs in most areas. However, population growth, industrial expansion, and development in agricultural and recreational activities in the basin have approached the limit at which available water resources in their present state of development can meet the total demand for relatively pure water.

The ground water resources of the Potomac River basin vary significantly by physiographic regions. In the Coastal Plain several aquifers are capable of consistently supporting wells which will yield 100,000 gallons of water per day. In general, the water is satisfactory in chemical quality for most uses, but the low mineral content and low pH cause the water in some areas to be corrosive.

The Piedmont region is underlain by a variety of rocks consisting mostly of metamorphosed sedimentary and igneous rocks but including large areas of shale and sandstone of Triassic Age and some slightly altered granite rocks. While some large capacity wells do exist, there are no significant areas where wells producing as much as 100,000 gallons per day can be developed.

In the Appalachian Valley the underlying rock strata is chiefly a thick-bedded, blue dolomitic limestone with clay laminae and beds of dolomite, sandstone, and limestone conglomerate. Wells in this region must go deep and the yields are small. In most areas the water obtained is very hard. However, throughout the valley, other alluvial deposits occupying the lower parts of the mountain slopes may be potential sources of large ground water supplies.

In the Appalachian Ridgesregion there are several formations which carry large supplies of ground water. However, large-scale development is not practical because they are remote, occupy mountainous terrain, and frequently dip beneath valleys under unknown thicknesses

of relatively unproductive rocks.

The Appalachian Plateau is underlain with rock, chiefly of alternating beds of sandstone and shale. Although the beds are nearly horizontal, quantitative estimates are not practical because of remoteness and poor definition of recharge areas. Because of this lack of information and their topographic and geologic positions, they are not considered to lend themselves to large-scale development.

The principal water uses in the Potomac River basin are for municipal and industrial water supply, water quality control, and recreational purposes. Water for irrigation is a relatively small but important use requirement. The use of the streams for disposal and dilution of municipal and industrial wastes is of great importance. While this is a proper use if accomplished under adequate control, indiscriminate dumping of sewage and other wastes into the streams without proper treatment has affected water quality and thus reduced usable supplies in many areas.

Water resource development, to be most effective, will require the coordinated efforts of all interests and the integration of conservation, land treatment, and upstream structural measures with water management measures on the main stem and major tributaries.

14. PROBLEMS OF WATER QUALITY

Pollution of the waters of the Potomac River and its tributaries has been a growing problem for nearly a century. Discharge of industrial waste became serious early in this century, particularly in the areas of the North Branch and in the Shenandoah Valley. Acid waters draining from coal mines contributed to the deterioration of the water quality in western Maryland and West Virginia.

Pollution from sediment began causing concern in the 1860's and continued to become more serious with the further destruction of forests on the watershed and the continuance of poor land use practices. Sediment accumulation in the tidal estuary is a serious problem. Sediment deposition must be prevented in order to preserve the water areas and enjoy the benefits of other pollution control measures.

Sediment sources normally are sheet erosion, channel erosion, gully erosion, roadside erosion, and wind erosion. The most serious sources, volume-wise, are sheet erosion, channel erosion, gullying, and localized shoreline erosion in the lower Potomac. In most cases, sheet erosion accounted for more than 60 percent of the gross erosion and, consequently, a high percentage of the sediment production. The amount of soil loss from erosion depends on rainfall, hydrologic characteristics of the region, inherent properties of the soil material, and the vegetative cover.

Erosion and sediment yield are not synonymous because of progressive

deposition of eroded materials enroute from point of origin to areas further downstream. Sediment yield correlates with erosion to the extent that a decrease in the supply (erosion) results in some decrease in sediment yield.

Sediment yield is the total sediment outflow from a watershed. Delivery rates depend upon many factors. The transport efficiency and delivery rate of a steep, highly channeled watershed will be appreciably higher than that of a flat area. The delivery rate in small watersheds is usually high, gradually decreasing as the watershed size increases until it becomes a relatively small fraction of the gross erosion on watersheds exceeding 100 square miles in size.

In the Coastal Plain region the sediment contribution from channel erosion is small due to the swamped condition of the small flood plains. Most of the sediment from this area is produced from sheet erosion and areas affected by the urban expansion.

Growth of the Washington, D.C., area in the past several decades has increased the sediment contribution in the Potomac River and its tributaries due to construction activities on the highly erodible soils. Yields have been estimated to be as high as 30,000 tons per square mile per year. This sediment adversely affects navigation, swimming, boating, other water-oriented recreation in the estuary, and the fish and marine life which were once abundant in the river.

The Piedmont region topography ranges from mountainous to nearly flat and gives rise to a variable sediment and erosion picture. Generally, the more erodible soils are on the more gentle slopes and are in crops and pasture. Sheet erosion is active in these areas. Gullying contributes a significant amount to the sediment yield of the region. Soils derived from sandstone and shales are readily erodible and, therefore, gully very easily. The flood plains are of various widths, dependent on the resistance of the underlying strata, and flood plain scour is significant in the wide flood plains subject to frequent inundation.

The annual sediment delivery of the Potomac River at Washington, D.C., is estimated to be 1-1/2 million tons. The Piedmont region represents about 27 percent of the area contributing and yields about 23 percent of the sediment. The gross erosion in the Piedmont is high due to the high percentage of cultivated and open land. However, due to the nature and physical characteristics of the displaced material, the sediment yield is relatively low. The heavy material is dropped in the valleys and on the flood plains of the tributaries before it reaches the major streams.

In the Appalachian Valley the fertile soils are used extensively for crops and pasture and, as a consequence, the sheet erosion rates are somewhat higher than they are in the Piedmont. Gully erosion is not a large sediment source from the region as a whole, although some

severe gullying occurs. Flood plain scour is significant in the wide flood plains subject to frequent inundation. The stream density, however, is lower than for the two regions to the east.

The Appalachian Valley represents about 38 percent of the area contributing and yields about 47 percent of the sediment estimated to be entering the estuary at Washington. In addition to the gross erosion rates being high on the limestone soils, the delivery rate also is high because of the ease with which the finely divided soil particles can be transported. Once in suspension, they move down into the estuary and are precipitated out due to the low velocity and the saline waters in the estuary.

The Appalachian Ridges region is subject to only moderate sheet erosion even though there are many steep, long slopes. The region is mostly in forest cover, with some areas of upland pasture. For the most part, however, cropland is limited to flood plain areas. Channel erosion is active, and flood plain scour is significant on the cultivated bottom lands. In some flood plains, erosion is limited to streambank and channel erosion since most flows are confined within the banks. Areas with broad flood plains subject to inundation frequently suffer damage from sedimentation and infertile overwash. Gully erosion is neither serious nor widespread in this region.

The Appalachian Ridges region represents about 32 percent of the area contributing and yields 24 percent of the sediment downstream at Washington. The erosion and sediment production can be attributed mostly to the high gradient streams and the shale soils through which they flow.

In the Appalachian Plateau region erosion of exposed areas from the coal strip mining and the unprotected rolling ridge tops are the principal sources of sediment. The gross erosion and sediment production in this region is small but the rate is high. This region represents about 3 percent of the area contributing and yields about 6 percent of the sediment. The streams in this region are flashy and often overflow their banks. The valleys are V-shaped with virtually nonexistent flood plain.

Water temperature. The normal water temperature of the natural flow of the Potomac River and its tributaries offers little or no problem to the quality of the water. Most of the small streams are fed from springs or sub-surface flows of relatively cool water. Many of the streams flow through wooded areas which provide shade to the flowing stream and thereby aid in keeping temperatures relatively constant according to the season of the year.

The discharging of industrial wastes and process and cooling water into the river or its tributaries, however, does increase local water temperature. The increase in the temperature of the water reduces the solubility of oxygen. This, in turn, affects the rate at which the stream can assimilate organic wastes.

15. IMPACT OF WATER RESOURCE PROBLEMS ON LAND USE AND MANAGEMENT

The waterflow characteristics of the Potomac River and its tributaries are influenced by the geologic formations through which it flows. The basin is divided by nature into two distinct portions: the fast-flowing, frequently narrow and rocky upper reaches of the river whose tributaries become less precipitous as they approach tidewater; and the broad, relatively slow-flowing tidal portion below the fall line at Washington, D.C. These same geologic conditions contribute to the fact that only about 1/4 million acres of the land area are delineated as flood plain land.

The flood plains along the Potomac River and its major tributaries are inundated occasionally by large floods that cause considerable damage and inconvenience to agricultural and urban areas and to transportation and communication facilities.

In the upper reaches of the basin, the limited acreage of fertile bottom land has resulted in its intensive agricultural development. The use of these flood plain areas without adequate protection has increased the tendency for erosion and scour and made management of these areas more difficult. The flood plain areas below Washington, D.C., present a somewhat different problem. The drowned coastline and swamping of upper flood plains, due to sediment impaired drainageways, restrict bottom land use. The broad, flat uplands provide a more favorable environment for crops and, therefore, the lower basin flood plains are not as intensively used as they are in the upper reaches of the basin.

Perhaps the most serious water resources problem associated with land use and management is the effect of rapid overland flow and the resulting erosion on the soils of the basin. Due to soil erosion, crop yields have not shown the increases that could be expected as a result of improvements in technology and management. Yields have increased, but net returns have not increased proportionally. More and more of the farmers' receipts must be used to maintain productivity. As soils become badly eroded yields drop seriously and the lands are either abandoned or put into some less intensive use than crop production. The results of land deterioration are far-reaching. The steady drain of soil erosion and its effect contributes to the economic and social problems of the basin.

The effects of erosion are not limited to the individual farm or uplands where the first losses occur. Additional damage may occur miles downstream in the form of infertile sediment deposition on once productive alluvial soils in the flood plain. Stream channels may be seriously impaired by depositions from eroding uplands.

The water quality also affects its use for agricultural purposes. Although little water is used directly from the streams for domestic uses, much of the water for irrigation and stock watering comes directly from streamflow. Consequently, acid water discharged or drained from active or abandoned coal mines or sediment in the streams seriously lowers the quality and suitability of the water for these uses. In addition to the adverse effect of applying polluted water to crops, it damages or destroys the equipment used in the application and use of water. The same applies to its suitability for use as orchard spraying or food processing. Therefore, the water quality limits the type of agriculture which can be carried on along these polluted streams.

16. CONTRIBUTIONS OF THE USE, CONDITION, AND MANAGEMENT OF LAND TO THE WATER RESOURCE PROBLEM

The use and treatment of land usually is reflected in the high and low flows in the streams. The abuse of land or improper management of its cover in the headwaters area of a stream contributes to flash floods, accompanied by sediment that can choke a major downstream channel and present serious pollution difficulties for downstream users. This points up the close inter-relationship between the interests of users of land and water resources in all parts of a river basin.

Agriculture is the principal user of the land in the Potomac River basin. Slightly more than half (54 percent) of the lands within the basin are in forest cover. Crop and pasture land occupy 24 and 16 percent, respectively, of the total basin area. There has been relatively little change in this ratio between forest and cleared land during the last several decades. The way in which agriculture uses these land resources has a direct impact on the quantity and quality of the water resources available to other users.

The principal factors influencing present watershed conditions are: (1) soils; (2) quality of cover; and (3) management, including the use of land according to its capability.

<u>Soils</u>. The soils of the Potomac River basin divide somewhat naturally into six major soil groups according to their parent material or the physiographic locations in which they occur. The six major groups are: (1) shales, (2) sandstones, (3) limestones, (4) piedmont, (5) mountain, and (6) alluvial. The shale soils occurring on rolling and hilly lands are generally very shallow, relatively unproductive, of low water-holding capacity, and highly erodible if not protected with adequate cover. The sandstone soils, more deeply weathered and of coarser texture than the shales, respond well to management on the gentler slopes, absorb rainfall more readily, and are the least erodible of all groups. The agriculturally favorable limestone soils are the most fertile of the upland soils. Though subject to severe erosion, they respond readily to proper treatment. The rolling piedmont soils of crystalline rock origin

are comparable in fertility to the limestone. They, too, are very erodible. The mountain soils of the Blue Ridge and Allegheny Plateau are practically all in forest cover. Where good cover has been maintained, little erosion is evident and retardation of runoff is appreciable. Because these soils are often shallow and the slopes are steep, maintenance of a well-developed forest cover and humus layer is essential for maximum reduction of storm runoff. The level, fertile, alluvial soils occupying the flood plains present little or no problems of runoff or erosion, but are subject to damage by sediment deposition, swamping, bank cutting, and scour.

The soils of the basin have been classified into hydrologic soil groups on the basis of rate of intake of water at the end of long-duration storms occurring after prior wetting. The relationship that exists between rainfall and runoff from the various soil types, under various conditions of cover and management, can be predicted within reasonable limits.

Due to differences in their physical properties, soils vary in the quantity of water they will hold, in the rate at which water will enter the surface, and in the rate at which water will percolate downward to the water table or laterally to the stream channels. The depth, infiltration at the surface, and structure and texture have profound effects upon the rate and amounts of intake and water retention. Conditions that provide large pores within the soil mass for rapid infiltration and movement of water and air, combined with small pores for water retention, are very desirable. The grouping of individual soil particles into aggregates which resist the slacking action of water and resist crushing during tillage operations is an essential feature of good soil structure.

Cover. Vegetative cover is the product of climate, soil, topography, and man's activities. For a particular soil, the type and density of the cover determines to a large extent the rate at which water enters the soil and influences the amount of surface runoff. It influences the depth and distribution of the snow pack, the rate of snow melt, and the loss of water through evaporation and transpiration.

Despite the great range in type, all forms of vegetation show certain characteristics that are important in relation to infiltration and runoff. All vegetation is made up of three parts: the canopy of living and dead stems and leaves that stand clear of the soil, the accumulation of dead and decaying plant remains that lie on or in the soil profile, and the living and dead roots and sub-surface stems that permeate the soil.

The canopy above ground and the surface litter accumulation intercepts precipitation, insulates the soil, and retards wind movement near the soil surface. Vegetation at the soil surface obstructs the overland flow of water and the detachment and transport of soil material. Beneath the soil surface, to depths reached by roots, vegetation acts both directly and indirectly. Roots, by their growth and subsequent decay, permeate

the soil with materials that both binds it and aids the flow of water through it.

Management. Land cropped to grass and trees does not present as serious an erosion and runoff problem as land devoted to cultivated crops. The loss of water as runoff is inversely related by the plant cover. As plant cover decreases or deteriorates, erosion and runoff losses become progressively higher.

Flood damages in the tributaries and upper headwater areas of the Potomac are, on the average, equal to damages occurring from major floods on the main stem. The June 1949 storm referred to previously is an example of a more or less local storm of high intensity resulting in great local damage. Floodwater-retarding structures on the small tributaries and the use of conservation measures on the land would have reduced the damages.

Slightly less than 2 percent of the land in the Potomac River basin is without some degree of land use limitation. The remaining 98 percent is subject to some degree of permanent limitation in land use because of natural land characteristics. About half of this land is suitable for cultivation, with the corrective measures needed to protect the land in this use. The remaining half should be permanently protected with a cover of grass, or trees and shrubs. The lack of proper farm and forest management practices has resulted in severe erosion problems on about 1,350,000 acres, or about 15 percent of the land surface of the basin. An additional 1,040,000 acres, or about 12 percent, have been subjected to moderate-to-severe erosion. As a result of the active erosion, many additional acres of the lower slopes and flood plains are being damaged by deposition or infertile overwash.

Another serious loss from erosion is the reduction of the soil mantle and the depletion of the soil fertility. Both of these reduce the ability of watershed land to absorb and hold precipitation and runoff. In addition, the quality of stream water is affected. Sediment interferes with the self-purification processes, destroys fish and wildlife habitat, increases costs and difficulties in the purification of water supplies, and interferes with navigation by filling the channels.

More than three-fourths of the forest area is making less than an adequate contribution to the protection of the watershed and reduction of rapid runoff. Similarly, many of the crops grown and most of the pasture cover are providing less watershed protection than could be attained and maintained under better farm management. In addition to low productivity, lack of proper use and management results in increased flood runoff from these areas and a reduction of volume of water available as underground and return flow during dry periods.

In the Coastal Plain region the present ability of the forest cover to retard rapid runoff and protect against soil erosion is better than

average for the basin with nearly one-fourth of the area rated as "fair." However, because of soil characteristics and relatively gentle topography, this capability is of less consequence in regard to runoff and stream flows than in other regions of the basin.

In the Piedmont region the present ability of the forest cover to retard rapid runoff and to protect the soil from erosion is rated as "poor" for the entire forest area of this region.

In the Appalachian Valley region the present ability of the forest cover to retard rapid runoff and protect against soil erosion is rated as "fair" for about one-third of the area, principally the public forests, and as "poor" on the remaining two-thirds.

In the Appalachian Ridges region the average ability of the present cover to retard rapid runoff and protect against soil erosion is rated "poor." Less than one-fourth of the total forest area is rated as "fair" and nearly one-half of this is on the limited acreage of public forest.

In the Appalachian Plateau region the state-owned forests account for all of the 25,000 acres rated as "good" and a large percentage of the 62,000 acres rated "fair" in their ability to retard rapid runoff and protection against soil erosion.

Land use according to capability. The land capability classification is a systematic arrangement of different kinds of soil according to those properties, including slope and degree of erosion, that limit or restrict the use or determine the ability of the land to produce permanently without deterioration. The units used in classifying land are characterized by differences that significantly affect conservation practices, suitability of use, crop yields, and management requirements. Suitability for cultivation includes the use of farm machinery and capacity for significant yields of one or more crops with suitable treatment and protective measures. In interpreting what the land can do and what it needs, each soil characteristic is considered in relation to all others. There are eight land capability classes, four of which are suited for cultivation. The distribution of land use according to land capability classification in the Potomac River basin in 1958 is shown in table 1.

Classes suitable for cultivation are differentiated according to the degree of permanent limitation in land use that is necessary because of natural land characteristics. They are, therefore, correlated with the general level of treatment or corrective measures needed.

Examination of the data in table 1 shows that most of the cropland areas appear in the first three land classes. However, over 500,000 acres, or about 25 percent, of the land devoted to crops are in classes IV, V, VI, VII, and VIII. The use of these land classes as cropland presents difficult management problems. Because these lands are being

Table 1 - Estimated Acreage in Each Land Use, 1958 1/
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other 2/		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	94,016	63.9	27,939	19.0	22,300	15.2	2,820	1.9	-	-	147,075	1.6
II	929,884	51.0	333,010	18.2	477,206	26.1	84,515	4.7	-	-	1,824,615	20.2
III	590,436	33.0	348,115	19.4	770,041	43.0	81,296	4.6	-	-	1,789,888	19.8
IV	300,362	22.6	277,117	20.9	703,085	53.1	45,056	3.4	-	-	1,325,620	14.6
V	10,951	18.3	10,329	17.3	36,692	61.4	1,774	3.0	-	-	59,746	0.7
VI	122,895	13.0	215,727	22.7	579,716	61.2	29,660	3.1	-	-	947,998	10.5
VII	64,040	2.5	272,759	10.4	2,220,822	85.1	53,265	2.0	-	-	2,610,886	28.8
VIII	1,012	0.9	3,062	2.6	99,819	86.2	11,984	10.3	-	-	115,877	1.3
Unclassified 3/	3,065	1.4	4,203	1.9	21,884	9.7	37,400	16.6	158,309	70.4	224,861	2.5
Totals	2,116,661	23.4	1,492,261	16.5	4,931,565	54.5	347,770	3.9	158,309	1.7	9,046,566	100.0

1/ Source of data: "Potomac River Basin Tables of Agricultural Basic Data Estimates." Excludes water.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

used beyond their capability, they often are the source of high runoff and high sediment production, thus contributing to the water resource problems.

17. IMPACT OF FUTURE LAND USE, CONDITIONS, AND MANAGEMENT ON THE WATER RESOURCES

Since geology and topography are fixed characteristics of a drainage basin, it follows that variations in the rainfall-runoff relationship within a drainage basin are the reflection of variations in the weather and changing uses being made of the land. In estimating the effects of future land use, condition, and management on the water resources of the Potomac River basin, two points must be considered: (1) the amount of land that will be converted to uses that decrease infiltration and increase runoff, such as rooftops and pavements; and (2) the type of management to be given the land remaining in natural and cultivated vegetative cover. Both will affect the basin's hydrology.

A study of the land use trends from 1938 to 1958 provided the basis for projecting future growth patterns for the basin, assuming relatively free choice of land quality by investors and builders. The findings of the study indicated that in areas where there is a non-farm demand for land now in agricultural use, a premium will be paid for accessibility but not for the characteristics that make the land responsive to agricultural uses unless those characteristics are important also in its new use. Conversely, in areas where non-farm demand is relatively slight, as in the Ridge and Valley areas of the basin, agricultural users will pay a premium for responsiveness of land to agricultural use as well as for accessibility.

Although projected rates of land use change vary widely within the basin, and even though counter-trends in certain land uses are likely to occur among physiographic regions and areas, some overall basin-wide trends are anticipated. Tables 2, 3, and 4 show the trends from 1938 to 1958, and tables 5 and 6 show the anticipated trends to 2010. Among these are: (1) a decline in cropland acreage from 2,116,661 acres in 1958 to 1,644,000 in 1985, and a further decline to 1,191,000 acres in 2010; (2) a decline in pasture acreage from 1,492,261 acres in 1958 to 1,378,300 in 1985, and a further decline to 1,206,000 acres in 2010; (3) a decline in woodland acreage from 4,931,565 in 1958 to 4,874,100 in 1985, and a further decline to 4,601,200 in 2010; (4) an increase in high-density urban areas from 158,309 acres in 1958 to 425,700 in 1985, to a further increase of 795,200 acres in 2010; and (5) an increase in "other" acreage from 347,770 in 1958 to 724,337 in 1985, and a further increase to 1,252,000 acres in 2010. The combined "other" and urban classification is expected to account for 22.6 percent of the total land area in the basin by 2010.

Wide variations in expected land use changes within land use capability classes are anticipated. Variations in the rate of change during the 1952-58 period as shown in tables 3 and 4 will serve as an example.

Table 2 - Estimated Acreage in Each Land Use, 1938 [1/]
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other [2/]		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	26,769	59.0	34,523	23.5	20,053	13.6	5,730	3.9	-	-	147,075	1.6
II	960,572	52.6	333,494	18.3	468,566	25.7	61,983	3.4	-	-	1,824,615	20.2
III	671,091	37.5	330,091	18.4	729,634	40.8	59,072	3.3	-	-	1,789,888	19.8
IV	315,234	23.8	287,770	21.7	675,347	50.9	47,269	3.6	-	-	1,325,620	14.6
V	10,407	17.4	12,200	20.4	33,190	55.6	3,949	6.6	-	-	59,746	0.7
VI	130,212	13.7	208,082	22.0	555,335	58.6	54,369	5.7	-	-	947,998	10.5
VII	84,141	3.2	279,803	10.7	2,197,125	84.2	49,817	1.9	-	-	2,610,886	28.8
VIII	3,782	3.3	8,576	7.4	89,208	77.0	14,311	12.3	-	-	115,877	1.3
Unclassified [3/]	17,216	7.7	9,548	4.2	45,527	20.2	36,373	16.2	116,197	51.7	224,861	2.5
Totals	2,279,424	25.2	1,504,087	16.6	4,813,985	53.2	332,873	3.7	116,197	1.3	9,046,566	100.0

1/ Source of data: Airphoto comparison analysis. Excludes water.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

Table 3 - Estimated Acreage in Each Land Use, 1952 1/
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other 2/		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	92,042	62.6	28,149	19.2	20,795	14.1	6,089	4.1	-	-	147,075	1.6
II	945,381	51.8	325,927	17.9	481,850	26.4	71,457	3.9	-	-	1,824,615	20.2
III	620,101	34.6	337,198	18.9	767,820	42.9	64,769	3.6	-	-	1,789,888	19.8
IV	304,017	22.9	282,491	21.3	697,042	52.6	42,070	3.2	-	-	1,325,620	14.6
V	10,147	17.0	10,669	17.9	35,275	59.0	3,655	6.1	-	-	59,746	0.7
VI	121,057	12.8	223,008	23.5	572,472	60.4	31,461	3.3	-	-	947,998	10.5
VII	71,972	2.8	272,539	10.4	2,212,361	84.7	54,014	2.1	-	-	2,610,886	28.8
VIII	1,921	1.7	6,038	5.2	96,960	83.7	10,958	9.4	-	-	115,877	1.3
Unclassified 3/	10,977	4.9	5,691	2.5	31,184	13.9	33,915	15.1	143,094	63.6	224,861	2.5
Totals	2,177,615	24.1	1,491,710	16.5	4,915,759	54.3	318,388	3.5	143,094	1.6	9,046,566	100.0

1/ Source of data: Airphoto comparison analysis. Excludes water.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

Table 4 - Estimated Acreage in Each Land Use, 1958 1/
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other 2/		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	94,016	63.9	27,939	19.0	22,300	15.2	2,820	1.9	-	-	147,075	1.6
II	929,884	51.0	333,010	18.2	477,206	26.1	84,515	4.7	-	-	1,824,615	20.2
III	590,436	33.0	348,115	19.4	770,041	43.0	81,296	4.6	-	-	1,789,888	19.8
IV	300,362	22.6	277,117	20.9	703,085	53.1	45,056	3.4	-	-	1,325,620	14.6
V	10,951	18.3	10,329	17.3	36,692	61.4	1,774	3.0	-	-	59,746	0.7
VI	122,895	13.0	215,727	22.7	579,716	61.2	29,660	3.1	-	-	947,998	10.5
VII	64,040	2.5	272,759	10.4	2,220,822	85.1	53,265	2.0	-	-	2,610,886	28.8
VIII	1,012	0.9	3,062	2.6	99,819	86.2	11,984	10.3	-	-	115,877	1.3
Unclassified 3/	3,065	1.4	4,203	1.9	21,884	9.7	37,400	16.6	158,309	70.4	224,861	2.5
Totals	2,116,661	23.4	1,492,261	16.5	4,931,565	54.5	347,770	3.9	158,309	1.7	9,046,566	100.0

1/ Source of data: "Potomac River Basin Tables of Agricultural Basic Data Estimates." Excludes water.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

Table 5 - Estimated Acreage in Each Land Use, 1985 1/
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other 2/		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	75,762	51.5	22,558	15.3	22,633	15.4	14,225	9.7	11,897	8.1	147,075	1.6
II	759,732	41.7	289,126	15.8	428,534	23.5	256,224	14.0	90,999	5.0	1,824,615	20.2
III	403,003	22.5	355,502	19.9	729,776	40.8	199,452	11.1	102,155	5.7	1,789,888	19.8
IV	261,745	19.7	238,084	18.0	700,418	52.8	95,854	7.3	29,519	2.2	1,325,620	14.6
V	10,294	17.2	4,818	8.1	36,399	60.9	5,949	10.0	2,286	3.8	59,746	0.7
VI	89,162	9.4	197,512	20.9	590,734	62.3	46,834	4.9	23,756	2.5	947,998	10.5
VII	40,617	1.5	265,551	10.2	2,242,823	85.9	56,764	2.2	5,131	0.2	2,610,886	28.8
VIII	836	0.7	1,093	1.0	101,514	87.6	10,754	9.3	1,680	1.4	115,877	1.3
Unclassified 3/	2,961	1.3	4,042	1.8	21,268	9.5	38,281	17.0	158,309	70.4	224,861	2.5
Totals	1,644,112	18.2	1,378,286	15.2	4,874,099	53.9	724,337	8.0	425,732	4.7	9,046,566	100.0

1/ Source of data: Modified projections of basic trends established by airphoto comparison analysis.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

Table 6 - Estimated Acreage in Each Land Use, 2010 1/
Potomac River Basin

Land use capability class	Land use within each capability class										Acreage distribution of capability classes	
	Cropland		Pasture		Forest		Other 2/		Urban			
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
I	58,963	40.1	19,870	13.5	21,744	14.8	24,394	16.6	22,104	15.0	147,075	1.6
II	609,476	33.4	291,963	16.0	340,640	18.7	383,236	21.0	199,300	10.9	1,824,615	20.2
III	230,143	12.8	305,305	17.0	632,659	35.3	384,441	21.5	237,340	13.4	1,789,888	19.8
IV	205,053	15.5	185,058	14.0	666,060	50.2	192,110	14.5	77,339	5.8	1,325,620	14.6
V	3,566	6.0	1,399	2.3	33,494	56.1	15,032	25.1	6,255	10.5	59,746	0.7
VI	48,172	5.1	182,585	19.3	552,958	58.3	93,737	9.9	70,546	7.4	947,998	10.5
VII	32,686	1.2	214,716	8.2	2,240,405	85.8	102,758	4.0	20,321	0.8	2,610,886	28.8
VIII	800	0.7	1,073	0.9	92,090	79.5	18,358	15.8	3,556	3.1	115,877	1.3
Unclassified 3/	2,961	1.3	4,042	1.8	21,190	9.4	38,281	17.0	158,387	70.5	224,861	2.5
Totals	1,191,820	13.2	1,206,011	13.3	4,601,240	50.9	1,252,347	13.8	795,148	8.8	9,046,566	100.0

1/ Source of data: Modified projections of basic trends established by airphoto comparison analysis.
2/ All land not specifically used for crops, pasture, or forest; includes idle land, roads, low density urban areas, etc.
3/ Land area for which no land use capability data are available.

The basin-wide average yearly decline of cropland acreage by land use capability was as follows: class II, 2,582 acres per year; class III, 4,944 acres; class IV, 609 acres; and class VII, only 1,322 acres. Conversely, in class VI, cropland showed an average annual increase of 306 acres.

The Appalachian Plateau region follows, to a degree, an accepted hypothesis that, unless urban and industrial economic forces are indicated, there is a lower rate of decline in the acreage in land use capability classes that are best suited to intensive cultivation. In this region for the period 1952 to 1958, the acreage of class II cropland declined at a rate of 153 acres per year; class VI at 141 acres per year; and class VII at 212 acres per year. In the Appalachian Plateau region, it is expected that nearly all of the acreage in capability classes IV, VI, and VII will shift from crop and pasture use to forest, recreation, and other non-farm uses. The acreages in classes II and III are expected to be used predominantly for agricultural purposes and specifically for crop and pasture production. These trends and projections indicate that the Appalachian Plateau is the only region which shows a tendency to run contrary to basin-wide trends. This is due to the limited amount of competition for non-farm use.

One of the major objectives of soil conservation is to bring about the conversion of land poorly suited to cultivation to less hazardous and often more productive uses. All of class V to VIII land needs to be protected by permanent vegetative cover.

Although the economics of individual farm operating units sometimes warrant exceptions, in general, it would be desirable to convert most of the class IV land to non-crop uses. From a hydrologic point of view, these conversions would be desirable even though it would be necessary to offset them by using some of the class I to III land now in pasture or woodland for additional cropland.

Projections for the future indicate relatively little net change in the forested acreage of the basin. However, there are rather significant changes predicted for the future use of the open lands. Class IV land now being used for crops is projected to decrease from about 300,000 to 200,000 acres by 2010. Class V land now being used for crops is projected to decrease from 10,000 to 3,500, and classes VI, VII, and VIII now in crops are projected to have a combined decrease from 188,000 to 82,000 acres by 2010.

Further examination and comparison of trends between 1952 and 2010, as shown in tables 3 and 6, reveals that land use changes are projected to occur within the land still in rural use and that which will be in strictly urban use. It will be noted that cropland and pasture acreage declines in every capability class. However, the land in forests in 2010 for class VII land increased by slightly more than 1 percent. Comparison of these tables show that slightly less than 1 million acres will be changed to "other" uses, such as idle lands; road rights of

ways, including clover leaf areas; and low density urban areas. These "other" uses are for the most part considered to be somewhat more conducive to infiltration than crop and pasture land and, therefore, will bring about an improved hydrologic condition. Conversely, the shift to urban use, which is projected to increase to about 6 percent, will result in less favorable hydrologic conditions, due to the intense clearing and reshaping of the land for housing development.

These improvements and changes in rural land use, together with some improvement in management and adequate protection against fire, are predicted to more than offset the unfavorable hydrologic aspects of the projected increases in urban development.

Soil-cover complex indices were developed to reflect the changes in streamflow anticipated as a result of the changes in land use, cover conditions, and management.

The modest reduction in peak flows and annual yields and the slight increases in low flows anticipated to result from these improvements were expressed through the changes in soil-cover complex indices numbers.

The development of unit hydrographs indicate that the peak flows would reduce in direct proportion to the reduction in runoff. This relationship will vary between watersheds and physiographic regions. The percentage in reduction of peak flows will vary with the amount and intensity of the rainfall, soil moisture conditions, and the season of the year. In general, the greatest reduction will occur in the summer when anticedent soil moisture conditions are low and cover is at its optimum.

The expected percentage of decrease in peak flows is progressively greater from the lower reaches to the headwaters. In and around Washington, D.C., little net change in hydrologic conditions and, hence, in peak flows in the tributary streams in that area is anticipated. Progressing upstream, the adverse hydrologic influences of urbanization and the greater effects of improved use and management indicate a progressively greater decrease in peak flows.

It is assumed that these changes will be accompanied by changes in low flow. With improvement in hydrologic conditions, more of the precipitation from a given intensity storm will infiltrate into the soil. Small watershed studies have indicated that approximately one-half of the additional infiltration will find its way by lateral seepage and subsurface channels to the stream channels to augment low flows. An indication of the change in low flows is derived by using one-half of the reduction in surface runoff.

The effect of land treatment on annual water yields has not been fully determined. However, certain evident effects can be concluded from established data. With improvement in hydrologic conditions, more water will infiltrate into the soil. Considering that this will allow greater transpiration and that indeterminate "losses" to deep percolation

will increase, it was assumed that there would be a tendency toward slight decreases in gaged annual yields with improvements in land treatment and cover management. To provide an indication of the projected effects, percentage decreases in annual yield were calculated as one-fourth of the increase in low flows. Slight decreases in annual yields are indicated in all the physiographic regions of the basin except Region One.

Contingent upon land treatment as indicated by the National Inventory of Conservation Needs, sediment yields will decline by 30 to 40 percent in areas located far enough from the Washington metropolitan area to be out of the sphere of intense urban development due to the revised land use and the effect of conservation practices on the land. However, future urban expansion around the Washington area can be expected to yield sediment loads of the same magnitude as at present, unless some control of the present methods of land clearing which produce these high erosion and sediment rates is invoked. High sediment yield will continue until full development is reached and only then will it decline to the normal low soil-loss rate for established urban areas.

Examination of the data contained in tables 7 through 10 shows the estimated needs for conservation treatment on expected acreages of cropland, pasture, woodland, and other lands for the year 1985.

An analysis of the tables indicates that, at the present rate of progress, it will take from 50 to 75 years to establish most of the needed conservation practices on agricultural and other lands of the basin to provide the adequate treatment and high level of management required to bring about the improvements desired.

18. PRESENT DEMAND FOR WATER BY RURAL USERS

Rainfall in the Potomac River basin averages about 38 inches annually. Normally it is rather evenly distributed over the growing season and adequate for producing crops. However, a drought-damage study established that drought is a rather serious problem in the agricultural economy of the basin. The 1957 drought caused damages which might be expected approximately once in 15 years, while droughts of less magnitude may be expected more frequently. An appraisal of drought damage to agricultural crops in 1957 placed the aggregate damage in excess of $30 million. Average annual drought losses are estimated to exceed $12 million. Droughts occurring in May and June have serious effects on crops, such as vegetables and small fruits, while fall and winter droughts affect the yield of winter grain crops.

In recent years there has been a rapid increase in the use of irrigation water in the Potomac River basin. Prior to World War II, less than 100 acres were under irrigation in the basin. Advances in technology and several years of severe drought in the early fifties spurred irrigation development to approximately 7,500 acres by 1957. The amount

Table 7 - Estimates of Needs for Conservation Treatment of Expected Cropland Acreage, 1985
Potomac River Basin

County	Portion of co. in basin	Land with no problems which limit use	Land on which dominant problem is erosion by wind, water, or both			Land on which dominant problem is excess water			Land on which dominant problems are caused by unfavorable soil conditions		
	(percent)	(total acres)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)
Region One - Coastal Plain											
Prince Georges	54	840	19,740	4,590	15,150	8,210	2,808	5,402	3,785	2,677	1,108
Charles	90	1,468	15,737	3,222	12,515	28,383	8,752	19,631	3,796	700	3,096
St. Marys	70	939	20,449	5,878	14,571	36,158	2,977	33,181	2,142	42	2,100
King George	64	5,488	7,421	2,600	4,821	2,202	987	1,215	608	304	304
Northumberland	54	6,975	10,100	1,228	8,872	4,778	1,193	3,585	298	246	52
Westmoreland	81	10,812	18,760	2,025	16,735	5,545	1,455	4,090	6,629	2,903	3,726
Totals		26,522	92,207	19,543	72,664	85,276	18,172	67,104	17,258	6,872	10,386
Region Two - Piedmont											
Adams	48	1,029	53,212	12,000	41,212	19,452	5,868	13,583	1,073	344	729
Carroll	48	1,097	50,259	17,218	33,041	1,295	551	744	-	-	-
Frederick	100	10,343	156,698	50,491	106,207	8,536	1,414	7,122	-	-	-
Montgomery	90	1,671	57,814	16,333	41,481	5,809	2,354	3,455	-	-	-
Fauquier	100	101	72,033	29,000	43,033	19,126	6,226	12,900	1,178	778	400
Fairfax	100	-	8,380	2,765	5,615	2,171	695	1,476	449	200	249
Loudoun	100	-	71,380	28,602	42,778	11,355	3,975	7,380	10,393	5,485	4,908
Prince William	100	-	21,003	6,931	14,072	4,858	1,263	3,595	2,856	942	1,914
Stafford	70	700	8,376	3,138	5,237	2,232	589	1,643	-	-	-
Totals		14,941	499,155	166,478	332,676	74,834	22,935	51,898	15,949	7,749	8,200
Region Three - Appalachian Valley											
Washington	100	14,290	84,801	26,060	58,741	5,398	1,132	4,266	22,203	5,708	16,495
Franklin	80	6,373	120,330	26,240	94,090	8,354	4,016	4,338	24,914	10,400	14,514
Berkley	100	4,494	45,747	18,962	26,785	7,827	2,113	5,714	650	300	350
Jefferson	100	11,010	46,564	16,969	29,595	966	360	606	5,500	2,000	3,500
Frederick	100	2,284	38,823	12,000	26,823	2,158	300	1,858	8,842	2,000	6,842
Augusta	75	726	66,461	23,019	43,442	6,638	1,313	5,325	4,209	1,500	2,709
Clarke	100	689	18,805	8,500	10,305	-	-	-	1,744	600	1,144
Page	100	894	33,483	12,525	20,958	3,357	557	2,800	6,850	3,170	3,680
Rockingham	100	1,044	94,023	33,328	60,695	5,081	2,286	2,795	3,820	3,591	229
Shenandoah	100	1,035	35,647	12,120	23,527	7,770	1,554	6,216	1,828	366	1,462
Warren	100	-	8,072	2,400	5,672	1,149	449	700	63	23	40
Totals		42,839	592,756	192,123	400,633	48,698	14,080	34,618	80,623	29,658	50,965

Table 7 (cont.) - Estimates of Needs for Conservation Treatment of Expected Cropland Acreage, 1985
Potomac River Basin

County	Portion of co. in basin	Land with no problems which limit use	Land on which dominant problem is erosion by wind, water, or both			Land on which dominant problem is excess water			Land on which dominant problems are caused by unfavorable soil conditions		
	(percent)	(total acres)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)
					Region Four - Appalachian Ridges						
Pendleton	100	2,337	22,197	7,000	15,197	2,269	600	1,669	5,779	606	5,173
Grant	100	1,500	16,058	8,612	7,446	2,547	1,272	1,275	831	831	-
Hardy	100	5,114	12,819	7,673	5,146	2,069	600	1,469	2,892	2,458	434
Hampshire	100	1,188	30,958	10,816	20,142	2,071	1,275	796	1,200	800	400
Mineral	100	355	18,927	6,327	12,600	6,015	3,015	3,000	2,352	722	1,630
Morgan	100	1,137	12,587	5,914	6,673	1,795	651	1,144	-	-	-
Allegany	100	3,524	20,709	5,062	15,647	5,228	1,800	3,428	38	18	20
Bedford	29	161	37,153	14,535	22,618	4,844	1,842	3,002	792	269	523
Fulton	66	1,400	40,346	12,104	28,242	1,428	572	856	219	219	-
Highland	26	-	1,054	416	638	360	143	217	284	142	142
Totals		16,716	212,808	78,459	134,349	28,626	11,770	16,856	14,387	6,065	8,322
					Region Five - Appalachian Plateau						
Somerset	10	231	13,102	1,240	11,862	1,007	345	662	275	85	190
Garrett	38	71	19,578	3,116	16,462	5,480	1,151	4,329	65	11	54
Totals		302	32,680	4,356	28,324	6,487	1,496	4,991	340	96	244

Table 8 - Estimates of Needs for Conservation Treatment on Expected Acreage of Pasture, 1985
Potomac River Basin

County	Portion of county in basin	Total pasture area	Area not needing treatment	Area needing treatment	Type of problem: Establishment of vegetation	Improvement of vegetative cover	Protection of cover from: Over-grazing	Erosion	Excess water	Water conservation
	(percent)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Region One - Coastal Plain										
Prince Georges	54	7,772	1,292	6,480	3,780	2,700	864	1,674	918	2,160
Charles	90	9,427	950	8,477	7,358	1,000	99	500	260	100
St. Marys	70	4,875	532	4,343	3,595	600	79	868	444	370
King George	64	7,197	3,092	4,105	3,078	1,027	166	-	2,857	166
Northumberland	54	4,200	1,009	3,191	2,592	594	1,188	27	1,419	1,188
Westmoreland	81	4,658	1,511	3,147	2,228	919	2,025	32	1,457	1,620
Totals		38,129	8,386	29,743	22,631	6,840	4,421	3,101	7,355	5,604
Region Two - Piedmont										
Adams	48	16,589	4,800	11,789	4,109	6,864	480	-	5,520	-
Carroll	48	44,259	15,117	29,143	15,012	6,901	2,810	2,914	9,676	8,880
Frederick	100	104,549	22,784	81,765	29,136	36,394	12,235	5,000	4,000	20,000
Montgomery	90	80,898	15,546	65,352	26,125	39,227	6,535	1,307	12,961	-
Fauquier	100	104,782	50,689	54,093	34,093	20,000	6,000	400	16,000	-
Fairfax	100	14,000	4,000	10,000	7,500	2,500	2,700	100	4,800	-
Loudoun	100	68,082	38,069	30,013	15,412	14,601	8,000	500	10,195	-
Prince William	100	18,307	6,500	11,807	6,000	5,807	3,700	200	7,763	-
Stafford	70	10,847	3,424	7,422	6,444	979	441	245	2,113	-
Totals		462,313	160,929	301,384	143,831	133,273	42,901	10,666	73,028	28,880
Region Three - Appalachian Valley										
Washington	100	40,728	8,148	32,580	9,774	20,356	1,250	2,850	1,668	8,830
Franklin	80	38,340	22,900	15,440	6,400	8,000	560	80	4,080	-
Berkley	100	32,310	6,000	26,310	3,680	15,780	6,850	1,500	1,500	8,000
Jefferson	100	38,558	19,000	19,558	1,542	13,188	8,000	765	1,151	1,874
Frederick	100	64,678	26,200	38,478	26,000	12,478	12,000	3,000	4,000	-
Augusta	75	127,294	52,294	75,000	15,000	60,000	15,000	1,500	4,875	-
Clarke	100	37,171	19,000	18,171	10,000	8,171	4,290	1,000	297	-
Page	100	28,404	10,000	18,404	7,268	11,136	1,500	1,000	1,200	-
Rockingham	100	135,170	60,826	74,344	8,443	65,901	24,533	594	7,277	-
Shenandoah	100	77,828	40,471	37,357	15,894	12,491	8,972	1,020	3,357	-
Warren	100	38,393	15,800	22,593	4,000	18,593	3,000	1,500	4,548	-
Totals		658,874	280,639	378,235	108,001	246,094	85,955	14,809	33,953	18,704

Table 8 (cont.) - Estimates of Needs for Conservation Treatment on Expected Acreage of Pasture, 1985
Potomac River Basin

County	Portion of county in basin	Total pasture area	Area not needing treatment	Area needing treatment	Type of problem: Establishment of vegetation	Type of problem: Improvement of vegetative cover	Protection of cover from: Over-grazing	Protection of cover from: Erosion	Protection of cover from: Excess water	Protection of cover from: Water conservation
	(percent)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Region Four - Appalachian Ridges										
Pendleton	100	83,063	20,000	63,063	3,000	60,063	20,000	1,000	-	1,000
Grant	100	59,532	17,673	41,859	1,346	30,103	3,100	345	1,488	8,464
Hardy	100	59,758	32,451	27,307	2,000	15,307	15,000	3,418	1,592	6,000
Hampshire	100	53,900	21,236	32,664	6,225	20,000	6,000	1,178	1,400	6,800
Mineral	100	31,808	11,000	20,808	3,000	17,808	2,000	600	1,500	2,000
Morgan	100	11,833	1,342	10,491	8,741	1,750	-	5,077	800	5,000
Allegany	100	21,995	2,267	19,728	5,331	11,445	1,800	3,050	3,268	900
Bedford	29	16,854	2,755	14,099	3,625	9,459	580	174	2,320	-
Fulton	66	14,569	2,117	12,452	7,133	3,934	594	462	587	-
Highland	26	14,540	7,410	7,130	2,060	4,940	260	240	780	-
Totals		367,852	118,251	249,601	42,461	174,809	49,334	15,544	13,735	30,164
Region Five - Appalachian Plateau										
Somerset	10	4,675	1,177	3,498	900	2,408	100	40	1,160	-
Garrett	38	12,772	3,230	9,542	1,140	6,844	418	190	1,140	95
Totals		17,447	4,407	13,040	2,040	9,252	518	230	2,300	95

Table 9 - Estimate of Conservation Measures and Practices Needed on Expected Future Forest Area by Regions
Potomac River Basin

Region and sub-area	Establishment and reinforcement of timber stand	Improvement of timber stand	Protection of timber stand from			Erosion control
			Fire	Insect and disease	Animals, including rodents	
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Region One - Coastal Plain						
Area A (Washington metropolitan)						
Prince George County, Md.	2,702	13,249	-	-	3,079	6,783
District of Columbia	-	-	-	-	-	-
Sub-total	2,702	13,249	-	-	3,079	6,783
Area B (Metropolitan supplement)						
Charles County, Md.	4,823	31,919	-	-	11,174	578
Area C (Tidewater)						
St. Mary's County, Md.	27,236	9,427	-	-	4,942	241
King George County, Va.	1,169	3,840	41,947	27,965	1,024	128
Northumberland County, Va.	3,057	6,500	36,569	24,379	-	-
Westmoreland County, Va.	3,160	9,085	66,489	44,326	790	-
Sub-total	34,622	28,852	145,005	96,670	6,756	369
Total - Region One	42,147	74,020	145,005	96,670	21,009	7,730
Region Two - Piedmont						
Area A (Metropolitan supplement 2)						
Carroll County, Md.	2,750	22,658	-	-	1,358	2,750
Frederick County, Md.	6,411	50,509	-	-	11,357	1,098
Adams County, Pa.	1,680	7,118	-	-	-	48
Cumberland County, Pa.	-	-	-	-	-	-
Loudoun County, Va.	3,607	8,309	78,590	52,394	17,000	100
Sub-total	14,448	88,594	78,590	52,394	29,715	3,996
Area B (Washington metropolitan 2)						
Montgomery County, Md.	3,086	11,275	-	-	7,999	433
Alexandria County, Va.	-	-	-	-	-	-
Arlington County, Va.	-	-	-	-	-	-
Fairfax County, Va.	5,710	38,931	104,950	69,996	9,600	150
Sub-total	8,796	50,206	104,950	69,996	17,599	583

Table 9 (cont.) - Estimate of Conservation Measures and Practices Needed
on Expected Future Forest Area by Regions
Potomac River Basin

Region and sub-area	Establishment and reinforcement of timber stand	Improvement of timber stand	Protection of timber stand from			Erosion control
			Fire	Insect and disease	Animals, including rodents	
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Region Two - Piedmont (continued)						
Area C (Metropolitan supplement 3)						
Fauquier County, Va.	7,485	36,856	84,834	56,549	10,600	159
Prince William County, Va.	1,000	11,181	77,714	51,886	7,980	200
Stafford County, Va.	1,224	19,741	67,003	44,670	3,828	92
Sub-total	9,709	67,778	229,551	153,105	22,408	451
Total - Region Two	32,953	206,578	413,091	275,495	69,722	5,030
Region Three - Blue Ridge-Great Valley						
Area A (North of Potomac)						
Washington County, Md.	2,710	47,204	-	-	8,071	1,250
Franklin County, Pa.	4,400	20,000	-	-	2,400	80
Sub-total	7,110	67,204	-	-	10,471	1,330
Area B (South of Potomac)						
Frederick County, Va.	9,200	41,020	136,735	91,156	24,500	200
Berkeley County, W. Va.	10,000	16,000	61,006	-	36,000	2,000
Sub-total	19,200	57,020	197,741	91,156	60,500	2,200
Area C (Shenandoah)						
Augusta County, Va.	2,836	42,302	95,226	63,477	19,883	669
Clarke County, Va.	2,289	16,026	45,789	30,526	4,300	100
Page County, Va.	3,254	12,862	57,129	38,049	9,247	250
Rockingham County, Va.	888	37,656	127,470	84,895	17,607	210
Shenandoah County, Va.	22,364	45,856	111,821	74,548	13,413	75
Warren County, Va.	20,000	30,000	66,789	44,526	30,000	40
Jefferson County, W. Va.	749	7,513	11,532	-	5,567	135
Sub-total	52,380	192,215	515,756	336,021	100,017	1,479
Total - Region Three	78,690	316,439	713,497	427,177	170,988	5,009

Table 9 (cont.) - Estimate of Conservation Measures and Practices Needed on Expected Future Forest Area by Regions
Potomac River Basin

Region and sub-area	Establishment and reinforcement of timber stand	Improvement of timber stand	Protection of timber stand from			Erosion control
			Fire	Insect and disease	Animals, including rodents	
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Region Four - Ridge and Valley						
Area A (North Branch)						
Bedford County, Pa.	348	16,530	-	-	970	232
Fulton County, Pa.	2,541	27,720	-	-	3,960	165
Allegheny County, Md.	10,266	105,000	-	-	28,500	1,706
Mineral County, W. Va.	12,000	40,000	95,629	-	35,000	200
Sub-total	25,155	189,250	95,629	-	68,330	2,303
Area B (South Branch)						
Morgan County, W. Va.	3,500	55,000	74,323	-	8,000	1,500
Hampshire County, W. Va.	1,900	45,000	202,023	-	48,800	900
Grant County, W. Va.	1,500	67,588	135,177	-	70,000	1,800
Hardy County, W. Va.	6,218	47,328	158,059	-	49,000	1,547
Pendleton County, W. Va.	5,500	75,000	144,411	-	80,000	500
Highland County, Va.	-	-	37,206	-	-	-
Sub-total	18,618	289,916	751,199	-	255,800	6,247
Total - Region Four	43,773	479,166	846,828	-	324,130	8,550
Region Five - Appalachian Highlands						
Area A (Appalachian)						
Somerset County, Pa.	869	8,250	-	-	165	92
Garrett County, Md.	6,290	66,600	-	-	16,563	1,110
Total - Region Five	7,159	74,850	-	-	16,728	1,202

Table 10 - Estimates of Needs for Conservation Treatment of Expected Acreage of Other Land, 1985
Potomac River Basin

County	Portion of co. in basin	Land with no problems which limit use	Land on which dominant problem is erosion by wind, water, or both			Land on which dominant problem is excess water			Land on which dominant problems are caused by unfavorable soil conditions		
	(percent)	(total acres)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)
Region One - Coastal Plain											
Prince Georges	54	455	8,246	5,535	2,711	6,467	4,320	2,147	3,756	2,136	1,620
Charles	90	110	1,494	413	1,081	9,126	7,825	1,301	1,660	450	1,210
St. Marys	70	291	2,294	2,159	135	6,027	4,797	1,230	1,117	627	490
King George	64	207	1,754	1,475	279	1,384	1,158	226	415	249	166
Northumberland	54	57	347	227	120	675	675	-	54	7	47
Westmoreland	81	-	174	81	93	692	567	125	-	-	-
Totals		1,120	14,309	9,890	4,419	24,371	19,342	5,029	7,002	3,469	3,533
Region Two - Piedmont											
Adams	48	297	6,274	4,985	1,289	3,137	2,976	161	550	423	127
Carroll	48	-	6,353	5,040	1,313	1,008	610	398	96	96	-
Frederick	100	483	14,469	8,190	6,279	2,129	1,725	404	2,336	2,201	135
Montgomery	90	457	24,822	9,793	15,029	3,092	1,431	1,661	50	50	-
Fauquier	100	-	17,832	9,000	8,832	4,288	1,500	2,788	1,290	900	390
Fairfax	100	55	7,613	4,000	3,613	1,537	1,000	537	2,147	1,500	647
Loudoun	100	-	4,599	3,099	1,500	2,030	1,726	304	3,208	2,952	256
Prince William	100	-	17,080	12,080	5,000	6,192	3,192	3,000	524	200	324
Stafford	70	-	1,516	923	593	961	894	67	311	156	155
Totals		1,292	100,558	57,110	43,448	24,374	15,054	9,320	10,512	8,478	2,034
Region Three - Appalachian Valley											
Washington	100	868	3,671	2,853	818	547	482	65	2,415	2,285	130
Franklin	80	450	17,377	14,977	2,400	3,112	3,112	-	2,480	2,000	480
Berkley	100	935	8,358	5,000	3,358	869	569	300	833	600	233
Jefferson	100	250	1,766	1,166	600	202	180	22	840	600	240
Frederick	100	30	4,355	2,000	2,355	1,391	200	1,191	3,072	2,272	800
Augusta	75	15	7,631	5,475	2,156	574	469	105	2,981	2,420	561
Clarke	100	-	1,425	230	1,195	-	-	-	1,025	725	300
Page	100	-	1,992	1,592	400	587	287	300	1,475	755	720
Rockingham	100	-	4,960	3,187	1,773	327	175	152	2,662	2,057	605
Shenandoah	100	-	2,800	840	1,960	-	-	-	2,646	1,089	1,557
Warren	100	41	744	372	372	-	-	-	2,417	1,200	1,217
Totals		2,589	55,079	37,692	17,387	7,609	5,474	2,135	22,846	16,003	6,843

Table 10 (cont.) - Estimates of Needs for Conservation Treatment of Expected Acreage of Other Land, 1985
Potomac River Basin

County	Portion of co. in basin	Land with no problems which limit use	Land on which dominant problem is erosion by wind, water, or both			Land on which dominant problem is excess water			Land on which dominant problems are caused by unfavorable soil conditions		
	(percent)	(total acres)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)	(total acres)	(acres treated)	(acres needing treatment)
					Region Four - Appalachian Ridges						
Pendleton	100	64	553	400	153	19	9	10	67	50	17
Grant	100	4	499	453	46	70	63	7	770	620	150
Hardy	100	105	1,156	916	240	473	273	200	-	-	-
Hampshire	100	108	2,596	2,000	596	421	380	41	178	178	-
Mineral	100	5	1,474	300	1,174	45	20	25	89	20	69
Morgan	100	404	4,699	4,000	699	798	700	98	-	-	-
Allegany	100	10	3,713	2,977	736	722	242	480	1,181	1,181	-
Bedford	29	20	9,628	7,691	1,937	1,308	1,245	63	532	431	101
Fulton	66	-	6,779	5,221	1,558	473	423	50	266	240	26
Highland	26	-	385	299	86	111	64	47	555	390	165
Totals		720	31,482	24,257	7,225	4,440	3,419	1,021	3,638	3,110	528
					Region Five - Appalachian Plateau						
Somerset	10	74	3,759	2,031	1,728	290	232	58	641	468	173
Garrett	38	-	4,253	3,817	436	788	622	166	1,786	1,701	85
Totals		74	8,012	5,848	2,164	1,078	854	224	2,427	2,169	258

of water used for irrigation in 1957 was approximately 4,000 acre-feet, which is very small in comparison to other uses.

In most of the eastern humid region, irrigation is used primarily to supplement natural rainfall and to improve an existing form of agriculture. The fundamental use of irrigation in the Potomac River basin is to prevent damage from periods of drought resulting from the erratic distribution of natural rainfall during the growing season. Benefits from irrigation occur in several ways: (1) Average yields are increased; (2) quality of the product is maintained at high level; (3) fluctuations in production that cause harvesting and marketing problems are reduced; (4) production and quality during seasons of severe drought provide higher than normal monetary returns; and (5) assured moisture supply allows the maximum use of other inputs, such as fertilizer. The greatest irrigation benefits accrue generally to crops of high value, such as vegetables, nursery stock, fruits, and tobacco. These crops are highly responsive to an application of water at a critical time in the growth stage. In general, these crops have shown the greatest percentage increase in irrigated acreage in the East.

In the Potomac River basin, 45 percent of the 1957 irrigated area was in corn, hay, and pasture crops grown to support livestock enterprises. These crops are of medium market value. In the case of livestock feed, however, production is used primarily on the farm. The value of livestock feed must be considered as equal to the value of alternative supplies. For example, in the case of pasture for dairy cows, drought damage is considered by the farmer as the value of hay or other winter feed which he must buy and feed to maintain production during drought. In effect, irrigation serves as a stabilizing factor to a livestock enterprise. This helps to explain the expansion of irrigation to the medium valued crops, such as hay or pasture. Economic trends toward higher land prices, higher capitalization per acre, and increasing improvement in management indicate that irrigation will become increasingly important in the agricultural economy of the basin.

Rural water needs other than irrigation are supplied from several sources within the basin. The chief source currently is from ground water. The ability of wells or springs to supply current needs varies somewhat with location. The Coastal Plain has ample supplies of underground water. The Piedmont may be described as an area of limited ground water supplies. Deep wells usually are necessary to provide large quantities of dependable supply. The shallow wells used on most farms may have limited capacity to exceed current demands. In the Appalachian Valley the underground supplies vary with location. In some parts of the Shenandoach Valley water must be hauled by truck during prolonged droughts. The underground supplies for the Appalachian Ridges and the Appalachian Plateau are highly variable, depending upon location within the area. Supplies in the valleys where most of the crop and livestock farms are located are more dependable than those in the upland areas. The total demand for water by rural users is a rather modest figure compared to the total basin needs. The 1960 requirement for rural domestic

water is estimated to be 12,590 million gallons; for livestock, 3,727 million gallons; and for other agricultural uses, including orchard spraying, 308 million gallons. These amount to an estimated 16,625 million gallons for the annual rural water requirements, excluding irrigation. Relative to other users in the basin, agriculture is a "small user" of water and an extensive user of land. Trends indicate that this relationship is likely to continue in the future.

The present demand for water for recreational uses in terms of surface area is difficult to determine. Water has served as a habitat for fish and wildlife on which early civilization fed and, more recently, hunted for sport. Demands for the recreational use of water, such as swimming, boating, fishing, hunting, and other water sports are growing and creating pressures from many groups, because of more time available for leisure and outdoor life and improved means of transportation. It is recognized that recreational use of water may compete with other water uses. However, in comprehensive river basin planning, facilities such as those for recreational use must be provided. Controlling floods, keeping water faucets flowing, and the wheels of industry turning are musts, but they are not enough. Man's desires as well as his basic needs must be considered. Statistics indicate that the demand for water-based recreation is greater than the supply. This applies with special emphasis in the Potomac Valley with its generally moderate climate and its nearness to major population centers. As the population grows and technologies improve, there will be more people with more time to spend on recreational pursuits. In some localities recreational revenues could become the major source of economic returns.

Conflicts with respect to water usage between agriculture and other users are less intensive in the Potomac than they are in many other river basins largely because the quantity is generally adequate. However, when the quantity is reduced in periods of drought, impairment in quality results in less suitability for diversified uses and more costly treatment in order to satisfy uses, such as water for food processing or other agricultural purposes.

19. FUTURE DEMANDS FOR WATER IN RURAL AREAS BASED ON PROJECTED DEVELOPMENTS

The development of irrigation in the Potomac River basin is important in the evaluation of the future water needs for the following reasons: (1) The location of the development may create localized shortages in an area of competing users during periods of drought; (2) since the primary source of water for irrigation is from surface supplies, it may be direct competition in several areas with such uses as municipal water supply and water quality control; (3) irrigation requires large amounts of water per acre and, properly applied, is a completely consumptive use; and (4) the peak demand for irrigation water usually occurs during July, which is also a peak demand period for residential and other non-farm uses, although record low flows of surface streams usually occur during August and September.

In spite of these apparent problems, the projected irrigation requirements cause little or no conflict with other uses for water because

the areas irrigated are widely scattered over the basin and, in total, the water required is a relatively small percentage of the total basin requirements.

Currently, more than 400,000 acres of land physically suitable for irrigation lie within a reasonable distance of permanently flowing streams. It is estimated that during periods of severe drought there will be irrigation on approximately 25,000 acres of crop and pasture land by 1985 and on approximately 40,000 acres by 2010. This represents an average annual increase of approximately 3 percent. Figures 6 and 7 show the location and extent of the projected irrigation for 1985 and 2010, respectively.

The volumes of water estimated to meet the projected needs are approximately 10,600 acre-feet for the peak month (July) and a seasonal total of approximately 35,200 acre-feet for the year 1985. For the year 2010, the expected need is approximately 17,200 acre-feet for the peak month and a seasonal total of approximately 59,000 acre-feet. The peak month requirements amount to about 30 percent of the seasonal total.

The quantities of water required during the peak month to irrigate the estimated acreages for the two time intervals are shown by subwatersheds in table 11. The quantities have been converted to flow in cubic feet per second per day. These quantities were subtracted from the low flow in order to calculate the residual flow available to meet local and downstream water supply needs.

During the next 50 years the annual rural water requirements in the Potomac River basin, excluding irrigation, are expected to increase 500 percent. This increase is attributed primarily to rising standards of living among rural people and increasing population in rural areas. The non-farm population in rural areas and small towns is expected to increase from 1,083,500 to 2,021,700 by 2010, while the farm population is expected to decline from 207,700 to 134,300. As a result, total annual rural water requirements, exclusive of irrigation water, are estimated to increase from 17 billion gallons to 100 billion gallons. Approximately 98 percent of the projected increase is attributed to increased population and increased per capita use. Annual livestock requirements are estimated to increase from 3.7 million gallons to 5 billion gallons by 2010. Water required for orchard spraying and other agricultural uses is predicted to remain relatively constant at approximately 300 million gallons per year. A major part of the supplies necessary to meet projected requirements will be provided by ground water sources as at present. To supplement ground water, it is expected that farm reservoirs will be developed to meet livestock and other agricultural needs. The needs of the rural communities and small towns have been considered and provided for by larger withdrawals from surface streams or from storage in the upstream reservoirs.

The present and projected estimates of rural water requirements excluding irrigation, are shown by time intervals in tables 12 through 14.


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
POTOMAC RIVER BASIN
ACRES TO BE IRRIGATED IN 1985
(ESTIMATED)
SEPT 1962
●-Represents 100 Acres

Figure 6


Figure 7
ACRES TO BE IRRIGATED IN 2010
(ESTIMATED)
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
POTOMAC RIVER BASIN
●-Represents 100 Acres
SEPT. 1962

Table 11 - Estimated Irrigation Water Quantities by Sub-watersheds for Peak Month (July) Potomac River Basin

(MGM X .0515 = c.f.s. day)

Sub-watershed no.	c.f.s. day		Sub-watershed no.	c.f.s. day	
	(1985)	(2010)		(1985)	(2010)
7	0.7	0.7	36	7.9	13.1
8	1.5	1.5	37	8.6	10.7
10	0.8	0.7	38	0.7	2.4
11	1.6	1.4	41	5.0	10.9
12	0.8	0.7	42	9.1	22.8
13	2.4	2.1	43	5.8	17.8
14	0.8	0.7	44	7.9	11.8
16	0.7	0.7	45	3.6	3.5
18	2.8	6.4	46	1.3	5.5
21	0.8	0.7	47	0.6	5.3
22	0.8	0.7	48	0.6	0.5
24	0.8	0.7	49	0.6	1.6
26	2.2	2.1	50	6.0	11.4
27	2.8	2.7	51	2.8	5.3
28	10.3	14.3	52	2.0	3.7
29	9.1	13.8	53	1.4	6.9
30	1.4	1.4	54	0.0	3.1
32	11.4	17.8	55	3.6	5.5
33	6.4	9.5	56	2.1	2.8
34	7.9	15.5	57	5.3	8.6
35	7.2	9.5	67	3.0	2.4
			68	3.0	2.4
Sub-watersheds below Washington, D.C.					
58	0.6	1.6	61	0.8	1.6
59	2.8	4.6	62	0.8	0.8
60	0.8	1.6	63	0.0	0.8
			70	2.3	0.8

Note: Sub-watersheds 9, 15, 17, 19, 20, 23, 25, 31, 39, 40, 64, 65, 66, and 69 have no irrigation requirements. Sub-watersheds 71 through 77 are in the Coastal Plain and use ground water as the source of supply.

Table 12 - Estimated Annual Rural Water Requirements, Excluding Irrigation, 1960
Potomac River Basin

Physiographic region	Rural Domestic				Livestock	Orchard spraying	Total
	Farm	Resi-dential	Small town	Sub-total			
	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)
Region One - Coastal Plain	272	1,776	208	2,256	114	-	2,370
Region Two - Piedmont	625	5,524	635	6,784	1,172	39	7,995
Region Three - Appalachian Valley	663	1,397	396	2,456	1,610	226	4,292
Region Four - Appalachian Ridges	227	488	114	879	797	43	1,719
Region Five - Appalachian Plateau	53	77	85	215	34	-	249
Basin totals Million gallons	1,890	9,262	1,438	12,590	3,727	308	16,625
Acre-feet	5,800	28,400	4,400	38,600	11,400	950	50,950

Table 13 - Estimated Annual Rural Water Requirements, Excluding Irrigation, 1985
Potomac River Basin

Physiographic region	Rural Domestic				Livestock	Orchard spraying	Total
	Farm	Resi-dential	Small town	Sub-total			
	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)
Region One - Coastal Plain	687	8,763	486	9,936	44	-	9,980
Region Two - Piedmont	1,532	29,249	1,642	32,423	1,070	38	33,531
Region Three - Appalachian Valley	1,831	6,900	1,248	9,979	2,113	233	12,325
Region Four - Appalachian Ridges	794	2,406	303	3,503	1,000	45	4,548
Region Five - Appalachian Plateau	126	368	212	706	19	-	725
Basin totals Million gallons	4,970	47,686	3,891	56,547	4,246	316	61,109
Acre-feet	15,250	146,365	11,940	173,555	13,000	970	187,525

Table 14 - Estimated Annual Rural Water Requirements, Excluding Irrigation, 2010
Potomac River Basin

Physiographic region	Rural Domestic				Livestock	Orchard spraying	Total
	Farms	Resi-dential	Small town	Sub-total			
	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)	(million gallons)
Region One - Coastal Plain	757	12,408	512	13,677	37	-	13,714
Region Two - Piedmont	1,559	49,043	3,433	54,035	1,064	40	55,139
Region Three - Appalachian Valley	2,418	14,160	3,536	20,114	2,755	244	23,113
Region Four - Appalachian Ridges	1,011	4,892	664	6,567	1,180	46	7,793
Region Five - Appalachian Plateau	136	762	376	1,274	21	-	1,295
Basin totals Million gallons	5,881	81,265	8,521	95,667	5,057	330	101,054
Acre-feet	18,050	249,400	26,150	293,600	15,500	1,100	310,200

SECTION V - UPSTREAM STRUCTURAL MEASURES

20. THE ROLE OF THE UPSTREAM STRUCTURAL MEASURES

The upstream structural measures included in the plan are for flood prevention and sediment control in the upstream areas, and for the storage of water for water supply and water quality control, recreation, fish and wildlife, and other beneficial uses. They consist of single purpose dams for flood prevention, single purpose reservoirs for water supply and quality control and recreation, and multiple purpose structures combining two or more of these purposes. Land treatment measures are considered as the first increment in watershed improvement and are supplemented, where needed, by structural measures. Upstream structural measures provide permanent storage for water supply, water quality control, recreation, and temporary storage of runoff for flood prevention in small watersheds. Multiple purpose development of upstream sites usually provides the most economical storage to meet upstream needs.

The effects of such projects on low flows and annual yields will depend on the inflow-evaporation relationship, geology, and other factors at each site. Floodwater-retarding structures provide the highest degree of flood protection immediately downstream from the dams. For reaches further downstream, the degree of protection varies with the percentage of the watershed controlled.

Estimated effects of upstream measures for regulating flood flows augmenting low flows and the effect on annual yields are illustrated by data from the South Fork River. Peak flows produced by the 1949 storm were tabulated at two points on the South Fork (Moorefield) River. Hydrographs were prepared to determine the modifications effected at these two points by proposed land treatment and structural measures. At the Brandywine gaging station these measures would reduce the peak flow from a similar storm from 41,000 cubic feet per second to 12,000 cubic feet per second. At Moorefield, the reduction would be from 39,000 to 15,000 cubic feet per second.

Routings of two-year hydrographs through structures indicated that low flows would increase appreciably for a period after each major storm. Also, mean daily flows would increase slightly during the "wet" years but would decrease slightly during the "dry" years. Annual yields are estimated to decrease very slightly as a result of land treatment and the evaporation losses expected from the pool surfaces.

21. POTENTIAL FOR UPSTREAM STRUCTURAL DEVELOPMENT

In a number of sub-watersheds it was found that the low flows were not sufficient to meet the future water needs of the upstream areas. The solutions considered for meeting the water requirements consisted of development of ground water supplies, including wells and springs, and the

development of surface water resources by impoundments.

More than 2,500 potential damsites were located on topographic maps. A number of qualifying criteria were used to locate and select each site. These were: (1) capacity to store a minimum of 4 inches of runoff from the contributing drainage area; (2) height of the dam normally not to exceed 100 feet; (3) the pool area to be relatively free of obstructions and developments, such as main highways and railroads and small towns; and (4) the drainage area above the site to range between 1 to about 25 square miles.

Preliminary studies indicated that about 800 of these damsites had favorable topographic features and location in relation to local water problems and needs. These sites were investigated for storage for water supply and quality control, flood prevention, and recreation.

The basic requirements for water supply, water quality control, and flood prevention depend on the maintenance or regulation of streamflows. Recreational use of the water resources depends upon regulation of streamflows and provisions for the maintenance of adequate surface areas. In many instances, the requirements could be served best by multiple purpose structures. The same additional streamflow required to serve water supply needs also satisfied some of the water requirements. At most of the sites the topographic limits were such that the 3-year refill could be stored and also the 4 inches of direct runoff could be temporarily retained. The 3-year refill rate is the maximum supplemental storage provided in the structure based on the water yield per square mile of drainage area above the dam. The water yield was computed from the cumulative daily flow during the period of minimum flow recorded for the stream. Thus, where conditions warranted, many of the sites selected for a single purpose role also were analyzed for multiple purpose use. Multiple purpose use, where justified, showed the greatest excess of benefits over cost and, therefore, was considered to be the most economical solution to the water resource problems in the individual sub-watershed.

Table 15 shows the total number and project purpose of the structures by sub-watersheds included in the plan for the development of the water resources of the basin.

Table 15 - Number and Project Purpose of Structures by Sub-watersheds Included in the Plan for the Comprehensive Development of Water Resources Potomac River Basin

Sub-watershed no.	Total no. of structures	Project purpose of structures			
		Single purpose flood prevention	Single purpose water supply	Single purpose recreational use	Multiple purpose use
1	11	11			
3	2	2			
8	35	34			1
9	5	4			1
10	4	4			
11	7	7			
12	5	5			
15	3		3		
19	5	5			
20	6	5			1
21	24	21			3
22	9	9			
23	6	6			
24	8	8			
25	2	1			1
26	9	6	1		2
27	1		1		
28	22		22		
30	6	5			1
32	5	2	2		1
33	10	5	3	2	
34	28	12	10		6
35	26	22		2	2
36	22	3	8		11
37	15	10		3	2
38	3	3			
39	5	2		2	1
41	5	2	3		
42	9	1	8		
43	2		2		
44	3	3			
45	7	3	2		2
46	15	12	1		2
47	1		1		
50	2		2		
51	6	4	1		1
52	19	6	1		12
53	14	6	2		6
58	3				3
59	13	2			11
60	16	10			6
68	10	10			
69	2				2
71	4	4			
74	3	3			
Totals	418	258	73	9	78

22. WATER SUPPLY AND WATER QUALITY DEVELOPMENT

Investigations by the U. S. Geological Survey disclose that ground water is not available in any appreciable quantity in the basin except in a few locations. The results of the U. S. Geological Survey were included in the "Ground Water Inventory Interim Report" to the Corps of Engineers, dated January 1961.

The Department of Agriculture developed information to provide for the needs based upon full development of the upstream areas of the basin to the year 2010. The plan included single purpose reservoirs for water supply or water quality control or both and multiple purpose structures which include water supply or water quality control or both as one of the major project purposes.

The development of the surface water resources was considered to be the most practical and economical means of meeting the demand for any appreciable quantity of water. In areas where the deficiency was estimated to be small, it was assumed that the local communities or industries would depend on the development of ground water to meet the needs.

The water needs were determined from the daily flow requirements for water supply and water quality control, as furnished by the U. S. Public Health Service. The needs were based on the following criteria. The water requirements for water supply and quality control were used to balance the demands against the minimum flows (daily flow, 30-year frequency for water supply purposes, and the minimum 7-day flow, 10-year frequency for quality control) to determine whether a deficiency existed.

There were communities in seven tributaries above Washington, D.C., where development of the surface water resources was determined to be the most practical and economical means of meeting the local need for water supply and water quality. The tributaries are: (1) Moorefield River, (2) Conococheague Creek, (3) Antietam Creek, (4) Monocacy River, (5) North Branch Shenandoah River, (6) South Branch Shenandoah River, and (7) Opequon Creek. In addition, there were several small communities throughout the basin where water supply of suitable quality could be provided most economically from surface storage.

The structural plan for water supply and water quality improvement is discussed by physiographic regions beginning in the upstream or headwater reaches.

In the <u>Appalachian Plateau region</u> there were no population centers in the upstream areas that would benefit from storage of water for supply and quality improvement.

In the Appalachian Ridges region there are four upstream population centers that will benefit from storage for water supply and water quality control. They are Moorefield, Augusta, and Maysville, West Virginia, and McConnelsburg, Pennsylvania.

In addition, four single purpose upstream reservoirs, three on Town Creek and one on Tonoloway Creek, are included to provide water supply to Washington, D.C. These four will be built with the major reservoirs on Town Creek and Tonoloway Creek to reduce the initial costs and increase the efficiency of these two major reservoirs.

(1) The maximum estimated need at Moorefield is 39.7 cubic feet per second. The design minimum flow is estimated to be 10.0 cubic feet per second; therefore, 29.7 cubic feet per second are needed from storage. Three multiple purpose structures yielding 32.3 cubic feet per second can meet these needs.

(2) At Maysville, West Virginia, there is an estimated need of 0.4 cubic foot per second of flow from storage. One site developed to optimum as a multiple purpose structure and yielding 2.3 cubic feet per second can supply the needs.

(3) At Augusta, West Virginia, the estimated maximum need is 0.6 cubic foot per second of flow from storage. One structure can provide this need. This multiple purpose structure would yield 8.5 cubic feet per second of supplemental flow at optimum development.

(4) At McConnelsburg, Pennsylvania, there is an estimated need of 7.2 cubic feet per second of flow from storage. Three structures yielding 7.5 cubic feet per second can supply these needs. This amount of supplemental flow will provide adequately for water supply and stream quality at McConnelsburg, Pennsylvania. However, Knobesville, Pennsylvania, in the upper part of the watershed, has an estimated need of 0.4 cubic foot per second of flow for stream quality control, which was concluded not feasible to supply from storage.

In the Appalachian Valley region are located several of the largest urban areas in the basin, exclusive of the Washington metropolitan area. This, plus the fact that ground water resources are variable and limited in supply, gives rise to the greatest upstream demand for water from surface storage. Population centers in the area of Chambersburg-Greencastle, Pennsylvania, in the Conococheague sub-watershed; Mercersburg, Pennsylvania, on the West Branch of the Conococheague; Waynesboro, Pennsylvania, and Hagerstown, Maryland, on the Antietam; Charles Town, West Virginia, on the Opequon; and most of the population centers on the Shenandoah River and tributaries will benefit from surface storage.

(1) On the West Branch of the Conococheague, there is an estimated need of 0.7 cubic foot per second at Fannettsburg, Pennsylvania. One structure, yielding 1.4 cubic feet per second of supplemental flow, can supply the needs. This single purpose water supply reservoir will

augment the flow from the major reservoir on the West Branch. Together they will meet the needs of 44.0 cubic feet per second at Mercersburg and provide improvement in stream quality to the confluence of the West Branch and the Conococheague Creek.

(2) The estimated maximum requirement in the Conococheague Creek below Greencastle, Pennsylvania, is 182.0 cubic feet per second of supplemental flow. The estimated maximum requirements at Chambersburg, Pennsylvania, are 100.3 cubic feet per second of supplemental flow, of which 31.8 cubic feet per second is for water supply. Fourteen single purpose reservoirs, yielding 41.6 cubic feet per second, can meet the need for water supply at Chambersburg, Pennsylvania, and augment the flow from the major reservoir for stream quality. One single purpose reservoir, yielding 1.1 cubic feet per second, can supply water to the community of St. Thomas, Pennsylvania. Seven additional structures, yielding 37.2 cubic feet per second, will assist in improving the stream quality by augmenting the flow from the major reservoirs.

(3) The estimated need at Waynesboro, Pennsylvania, is 63.8 cubic feet per second of supplemental flow. Of this amount, 25.8 cubic feet per second are needed for water supply, and the remainder is for quality control. Three single purpose reservoirs will provide the water supply for Waynesboro, Pennsylvania. Collectively, these three will yield 26.5 cubic feet per second of supplemental flow, which is adequate for water supply needs at Waynesboro, Pennsylvania. Five additional structures, having a combined potential yield of 42.0 cubic feet per second of supplemental flow, will provide water for quality improvement below Waynesboro, Pennsylvania, Hagerstown, Maryland, and the lower reaches of the Antietam Creek above its confluence with the Potomac.

(4) The estimated maximum requirement below Martinsburg, West Virginia, is 150.6 cubic feet per second of supplemental flow for stream quality. The estimated maximum requirement at Winchester, Virginia, is 67.0 cubic feet per second of supplemental flow, of which 21.2 cubic feet per second is for water supply needs and 45.9 cubic feet per second is for water quality control.

Three single purpose reservoirs having a combined supplemental flow of 30.5 cubic feet per second will provide part of the water quality needs and will augment the supplemental flow of the major reservoir on the Opequon, which meets the needs at Martinsburg, West Virginia. An expansion of an existing diversion to 21.1 cubic feet per second from the North Fork of the Shenandoah will provide the water supply needs at Winchester, Virginia.

(5) There is an estimated maximum requirement of 13.5 cubic feet per second of supplemental flow at Hedgesville and DeHaven, West Virginia. One multiple purpose dam will provide this need for stream quality improvement. It will yield 16.3 cubic feet per second at maximum development.

(6) There is an estimated maximum requirement of 7.4 cubic feet per second of supplemental flow at the Mt. Clinton-Tom Brook-Lantz Mills area on the Lower North Fork of the Shenandoah. Three dams can provide for these needs. The combined supplemental flow of these structures is 8.0 cubic feet per second. This will provide adequately for the water supply and improvement in stream quality.

(7) There is an estimated maximum requirement of 4.6 cubic feet per second of supplemental flow for the Forestville-Edom-Linville area in the Upper North Fork of the Shenandoah. In addition, there is an estimated 159.0 cubic feet per second of flow from storage needed for stream quality in the Upper North Fork. Three structures can provide for part of the water needs by furnishing the water supply for the upstream areas and by augmenting the supplemental flow from the major reservoir on the Upper North Fork. Collectively, they will provide a supplemental flow of 32.7 cubic feet per second.

(8) In the North River there is an estimated maximum requirement of 78.3 c.f.s. per second of supplemental flow from storage in the Harrisonburg-Bridgewater-Dayton area, plus a need of 6.0 cubic feet per second in Rawley Springs-Mt. Clinton-Sparkling Springs area. Sixteen structures can provide this water need. Ten single purpose water supply reservoirs will yield 21.4 cubic feet per second at maximum development. Six multiple purpose dams are included, and the combined yield of the 16 structures at maximum development is 88.7 cubic feet per second. These yields will adequately provide for the water supply and the improvement in stream quality in the North River.

(9) In the Middle River there is an estimated maximum requirement of 57.0 cubic feet per second. A part of this requirement is 2.2 cubic feet per second in the upstream areas of Churchville, Jolivue, and Middlebrook, Virginia. Two structures supplying 10.0 cubic feet per second can meet the upstream water needs in this area for water supply and quality control above the major reservoir.

(10) There is an estimated maximum requirement of 244.2 cubic feet per second of supplemental flow from storage at Waynesboro, Virginia. Of this amount, a maximum of 39.2 cubic feet per second are needed for water supply at Waynesboro, Virginia. In order to supply the 205 cubic feet per second, it would be necessary to divert water from Middle River. The Corps of Engineers' studies indicate that a trunk pipeline to carry the effluent from Waynesboro to the confluence of North, Middle, and South Rivers is the most economical means of meeting all the needs for quality control. However, when this means is used there is need for an additional 10.0 cubic feet per second to maintain a flowing stream in South River, making a total need of 49.2 cubic feet per second. Eleven structures above Waynesboro will provide an estimated yield of 37.1 cubic feet per second of supplemental flow. Eight reservoirs located below Waynesboro are estimated to yield 16.3 cubic feet per second. Collectively, these structures will yield 53.4 cubic feet per second of supplemental flow, which is adequate to meet the needs estimated to be 49.2 cubic feet per second.

(11) In the Upper South Fork of the Shenandoah there is an estimated maximum requirement of 4.2 cubic feet per second of supplemental flow needed for the McGahaysville-Montivideo-Penn Laird-Keezletown area. Two multiple purpose dams can supply part of these needs.

(12) In Hawks Bill Creek there is an estimated 25.7 cubic feet per second of supplemental flow required to improve stream quality between Luray and the confluence of Hawks Bill Creek and the South Fork of the Shenandoah River. Four structures can provide a part of the water needs. Collectively, they yield 8.8 cubic feet per second of supplemental flow. This will leave a deficiency in stream quality water below Luray. The alternative would be to pipe the effluent from Luray directly to the South Fork of the Shenandoah.

(13) There is need for 3.2 cubic feet per second of supplemental flow for Boyce, Rippon, and Summit point along the main stem of the Shenandoah. Two structures, yielding 4.8 cubic feet per second, will supply these needs.

In the Piedmont region the greatest upstream need for water from storage occurs in the Monocacy River and tributary areas. In addition, there are some needs in Catoctin Creek, Bull Run, Goose Creek, Occoquan Creek, and Broad Run in Virginia.

(1) In the Thurmont, Maryland, area there is an estimated requirement of 8.3 cubic feet per second of supplemental flow from storage. Two dams will provide the needed supplemental flow. Collectively, they yield 8.6 cubic feet per second at maximum development.

(2) In the Emmitsburg, Maryland, area there is an estimated requirement of 9.6 cubic feet per second of supplemental flow from storage. Two dams will provide adequately for these needs. They will yield 12.6 cubic feet per second of supplemental flow at optimum development.

(3) In the Gettysburg-Littlestown area there is an estimated need for 65.7 cubic feet per second of supplemental flow from storage. Thirteen structures can supply all the water supply needs and most of the needs for water quality. Collectively, they will yield 49.2 cubic feet per second of supplemental flow. This will result in a deficiency of about 16 cubic feet per second of flow for stream quality improvement.

(4) In the Westminster-New Windsor-Union Bridge area there is an estimated need of 38.3 cubic feet per second of supplemental flow from storage. Eight dams can supply a part of these needs. Collectively, the yield from these structures is estimated to be 32.0 cubic feet per second of supplemental flow. This will adequately provide for the water supply needs, but there will be a slight deficiency in water for stream quality improvement. The amount of this deficiency will depend largely on how much of the effluent from Westminster is discharged into

tributaries of the Potomac River.

(5) In the Hillsboro-Mechanicsville area there is an estimated need of 1.2 cubic feet per second of supplemental flow from storage. One structure, yielding 1.8 cubic feet per second at maximum development, will provide the needed supplemental flow.

(6) In the Round Hill-Upperville-Middleburg area there is an estimated requirement of 2.9 cubic feet per second of supplemental flow from storage. Three structures can adequately provide these needs. Collectively, these structures yield 17.1 cubic feet per second at maximum development.

(7) In the Arcola-Sterling area there is an estimated requirement of 38.1 cubic feet per second of supplemental flow. Three structures, yielding 11.6 cubic feet per second of supplemental flow, can provide part of the needs of this area.

(8) In Manassas-Dulles airport vicinity there is an estimated requirement of 66.0 cubic feet per second from storage. Eleven dams will provide the needed supplemental flow. Collectively, they will yield 61.1 cubic feet per second. This will adequately provide for the needs of the sub-watershed.

(9) In the Warrenton-Nokesville-Calverton area there is an estimated requirement of 10.5 cubic feet per second of supplemental flow needed from storage. Seven structures have been proposed for development. Collectively, they will yield 43.7 cubic feet per second. This yield is more than adequate to provide the estimated requirements of the area but will help to meet the shortage in adjacent areas if needed.

There were no requirements for water supply or quality improvement from storage for the Coastal Plain region. According to the interim report on the ground water resources of the Potomac River basin prepared by the U. S. Department of the Interior, the five aquifers in the Coastal Plain are capable of consistently supporting wells which will yield 100,000 gallons per day. Therefore, it was concluded that ground water would meet the requirements.

A summary of the pertinent data for all structural measures needed for water supply and water quality control is shown in table 16.

23. DEVELOPMENT FOR REDUCTION OF FLOOD DAMAGES

The Department of Agriculture studied the flood damages, by reaches, within the sub-watersheds of the basin. An economic analysis of the costs and benefits indicated the number and location of the floodwater-retarding structures that will be necessary and justified to reduce the projected damages within a sub-watershed, based on the midpoint, for the next 50 years.

Table 16 - Upstream Structures Needed, By Time Intervals, for Water Supply and Water Quality Requirements Potomac River Basin

Sub-watershed and structure nos.	Flow added	Storage		Annual costs	Drainage area	Year needed	Purpose
		Water supply	Water quality control				
	(c.f.s.)	(acre-feet)	(acre-feet)	($/c.f.s.)	(sq. mi.)		
8-46	0.7	184		3,024	1.7	1965	*WS @ Fort Ashby
9-22A	0.4		300	1,200	3.4	1965	**QC @ Maysville
15-3	16.6	8,720		2,108	21.8	2003	WS @ Washington, D.C.
15-30	5.8	3,720		1,400	7.3	2002	" " " "
15-35	10.3	5,620		2,532	13.7	2004	" " " "
20-18	0.6		495	1,180	12.4	1965	QC @ Augusta
21-48A	14.8		8,630	2,540	17.2	1965	QC @ Moorefield
21-56A	12.9		7,570	2,770	15.1	1977	" " "
21-3A	4.6		2,568	5,600	4.6	2006	" " "
25-41	20.3	11,720		1,160	21.8	2008	WS @ Washington, D.C.
26-30	1.4	345	735	4,320	2.0	1990	WS&QC @ McConnelsburg
26-33	4.4	950	2,020	4,760	5.5	1965	" " " "
26-28	2.5		1,740	3,240	3.3	2002	QC @ "
27-9	1.4		1,250	3,000	2.1	1965	QC @ Mercersburg and Fannettsburg
28-36	2.6	1,710	570	5,120	3.8	1965	WS&QC @ Fayettsville
28-47	1.0		840	2,960	1.4	1987	QC @ Greencastle and Chambersburg
28-34	1.9		1,680	3,040	2.8	1988	" " " "
28-51	7.8		6,720	4,320	11.2	1990	" " " "
28-45	3.1		2,160	4,560	4.6	1991	QC @ Greencastle
28-43	1.2		410	5,080	4.1	1993	" " "
28-46	3.0		2,640	5,080	4.4	1994	" " "
28-33	2.9		2,520	5,320	4.2	1996	" " "
28-42	1.6		1,440	5,520	2.4	1999	" " "
28-40	4.8		4,140	6,640	6.9	2001	" " "
28-35	1.1		1,020	6,800	1.7	2004	" " "
28-41	5.5		4,740	8,160	7.9	2005	" " "
28-49A	14.4		12,180	1,440	20.3	1965	" " "
28-25A	8.1		6,900	1,880	11.5	1992	" " "

* Water supply
** Quality control

Table 16 (cont.) - Upstream Structures Needed, By Time Intervals, for Water Supply and Water Quality Requirements
Potomac River Basin

Sub-watershed and structure nos.	Flow added	Storage: Water supply	Storage: Water quality control	Annual costs	Drainage area	Year needed	Purpose
	(c.f.s.)	(acre-feet)	(acre-feet)	($/c.f.s.)	(sq. mi.)		
28-39	4.6		4,020	1,905	6.7	1995	QC @ Greencastle
28-30	2.2		1,980	2,400	3.3	1998	" " "
28-24	5.4		4,680	2,470	7.8	1997	" " "
28-31	2.0		1,200	2,760	4.0	1986	QC @ Chambersburg and Greencastle
28-20	1.3		1,140	2,800	1.9	2000	QC @ Greencastle
28-32	3.1		2,760	3,080	4.6	1989	QC @ Chambersburg and Greencastle
28-19	1.2		400	4,160	4.0	2002	QC @ Greencastle
28-18	1.1		960	4,160	1.6	2006	QC @ St. Thomas
30-26A	16.3		8,955	1,760	19.9	1965	QC @ DeHaven
32-8	4.2	1,073	2,177	3,160	6.5	1965	WS&QC @ Tom Brook
32-42	1.4		470	4,160	4.7	1965	QC @ Mt. Clinton
32-26	2.4	210	630	1,830	8.4	1965	WS&QC @ Lantz Mills
33-2	1.4	397	796	4,480	2.1	1965	WS&QC @ Forestville
33-23	4.5	1,254	2,508	4,800	6.6	1965	WS&QC @ Edom and Linville
33-68	26.8		21,546	2,360	37.8	2003	QC @ Broadway, Timberville and New Market
34-69	12.5		11,879	8,240	16.0	1965	QC @ Harrisonburg, Bridgewater, and Dayton
34-71	21.4		20,138	6,480	27.1	1965	" " " " "
34-54	0.8		270	3,240	2.7	1965	QC @ Mt. Clinton
34-65	6.1	1,250	2,500	4,840	11.9	1967	WS&QC @ Rawley Springs
34-28	3.5		3,413	2,400	4.6	1977	QC @ Mt. Solon
34-53	1.8		1,855	3,440	2.5	1985	QC @ Hinton
34-15	8.6		8,236	2,830	11.1	1995	QC @ Harrisonburg, Bridgewater, and Dayton
34-8	1.4		1,410	3,640	1.9	1999	" " " " "
34-55	1.7		1,706	3,960	2.3	2000	" " " " "
34-52	2.9		2,671	4,040	3.6	2001	" " " " "
34-40	2.1		2,077	4,280	2.8	2002	" " " " "
34-51	1.5		1,558	4,560	2.1	2003	" " " " "
34-2	1.2		1,261	4,560	1.7	2004	" " " " "
34-43	3.7		3,636	4,240	4.9	2005	" " " " "
34-41	3.1		3,042	4,800	4.1	2006	" " " " "
34-67	12.1		11,649	5,760	15.7	2007	" " " " "

Table 16 (cont.) - Upstream Structures Needed, By Time Intervals, for Water Supply and Water Quality Requirements
Potomac River Basin

Sub-watershed and structure nos.	Flow added	Storage: Water supply	Storage: Water quality control	Annual costs	Drainage area	Year needed	Purpose
	(c.f.s.)	(acre-feet)	(acre-feet)	($/c.f.s.)	(sq. mi.)		
35-22	4.6		2,840	2,440	8.0	1965	QC @ Christians Creek
35-82	5.4	3,479		3,050	9.8	1965	WS @ Churchville
36-32	1.5	1,240		2,760	2.6	1968	WS @ Waynesboro
36-42	3.6	2,520		3,520	6.0	1970	" " "
36-49	10.2	7,098		1,360	16.7	1965	" " "
36-46	3.6	2,550		2,600	6.0	1965	" " "
36-38A	2.3		1,660	3,880	3.9	1973	QC @ Greenville
36-36	2.2	1,615		3,880	3.8	1982	WS @ Waynesboro
36-50	7.9	5,482		4,680	12.9	1995	" " "
36-30	1.4	1,020		5,800	2.4	2006	" " "
36-15	1.2	892		6,440	2.1	2008	" " "
36-26	1.1	808		7,840	1.9	2009	" " "
36-10A	1.7		1,233	8,320	2.9	1994	QC @ Waynesboro
36-7	2.9		2,125	3,960	5.0	1990	" " "
36-6	2.3		1,658	2,920	3.9	1987	" " "
36-5	0.6		510	8,800	1.2	1996	" " "
36-3	2.1		1,487	5,160	3.5	1991	" " "
36-48	4.2		2,975	8,160	7.0	1993	" " "
36-2	2.9		2,125	2,990	5.0	1988	" " "
36-1	0.7		595	6,040	1.4	1992	" " "
36-47	0.9		638	3,840	1.5	1989	" " "
37-36	0.8	56	224	6,600	2.8	1965	WS&QC @ McGaheysville
37-42	0.8	125	498	3,520	1.4	1973	WS&QC @ Keezletown, Penn Laird, and Montevideo
41-24	12.4		9,999	1,640	30.3	2003	QC @ Winchester
41-62	14.8		9,207	1,040	27.9	1965	" " "
41-61	3.3		2,079	2,840	6.3	1965	" " "
42-59	20.9	6,960	10,440	2,720	29.0	1965	WS&QC @ Waynesboro
42-38	3.9	968	1,452	4,480	5.7	1965	" " " "
42-42	1.7	624	936	6,320	2.6	1994	" " " "
42-60	5.8		3,420	7,520	11.4	1965	QC @ Waynesboro
42-57	21.0		11,970	2,200	30.9	1971	" " "
42-32	10.3		8,820	2,640	14.7	1996	" " "
42-27	3.2		2,820	3,880	4.7	2007	" " "
42-26	1.7		1,560	2,360	2.9	2005	" " "
43-8	1.7	387	903	4,640	2.9	1965	WS&QC @ Ripon and Summit Pt.
43-34	3.1	696	1,625	2,880	5.1	1965	WS&QC @ Boyce

Table 16 (cont.) - Upstream Structures Needed, By Time Intervals, for Water Supply and Water Quality Requirements
Potomac River Basin

Sub-watershed and structure nos.	Flow added	Storage		Annual costs	Drainage area	Year needed	Purpose
		Water supply	Water quality control				
	(c.f.s.)	(acre-feet)	(acre-feet)	($/c.f.s.)	(sq. mi.)		
45-11	1.3		979	4,920	2.2	1965	QC @ Stanley and Luray
45-4	5.3		3,872	3,000	8.7	1965	QC @ Luray
45-7	1.0		801	4,320	1.8	1974	" " "
45-6	1.2		935	6,840	2.1	1977	" " "
46-28	5.0		5,382	1,360	6.9	1965	QC @ Middleburg and Aldie
46-78	9.8	4,118	6,178	2,800	13.2	1985	WS&QC @ Upperville
46-40	2.3	749	1,747	6,160	3.2	1985	WS&QC @ Round Hill
47-16	1.8	360	1,434	7,880	2.3	1965	WS&QC @ Mechanicsburg; QC @ Hillsboro
50-30	6.1	3,884	2,590	3,800	8.3	1965	WS&QC @ Thurmont
50-24	2.5		2,730	3,160	3.5	1998	QC @ Thurmont
51-2A	12.2	2,350	7,050	1,640	18.8	1969	WS&QC @ Fairfield; QC @ Emmitsburg
51-12	3.0		3,060	5,810	4.0	2004	QC @ Iron Springs
52-38A	3.1		3,276	3,020	4.2	1965	QC @ Gettysburg
52-39	2.4		2,574	4,515	3.3	1965	" " "
52-40	1.1		1,248	6,480	1.6	1965	" " "
52-43	13.4		13,962	2,440	17.9	1990	QC below "
52-4	2.8	332	1,328	5,170	5.3	1965	WS&QC @ Littlestown and Taneytown
52-34A	6.1		6,396	2,960	8.2	1966	QC @ Gettysburg
52-24A	7.0	1,466	5,866	3,760	9.4	1966	WS @ Gettysburg; QC @ Mummasburg
52-30	3.9		2,518	3,950	6.6	1973	QC @ Two Taverns
52-8	2.5		2,652	6,640	3.4	1974	QC @ Littlestown and Taneytown
52-37	1.6		1,716	10,700	2.2	1981	QC @ Gettysburg
52-32	2.7		2,887	6,510	3.7	1983	" " "
52-3	1.2		1,248	6,680	1.6	1985	QC @ Littlestown and Taneytown
52-26	1.4		1,482	7,840	1.9	1987	QC @ Gettysburg
53-24	3.5		2,700	2,760	5.4	1965	QC @ Unionville
53-28	2.6		2,280	5,290	3.8	1965	QC @ Pleasant Valley
53-54	1.7	468	1,404	6,245	2.4	1965	WS&QC @ Medford; QC @ Union Bridge and New Windsor

Table 16 (cont.) - Upstream Structures Needed, By Time Intervals, for Water Supply and Water Quality Requirements
Potomac River Basin

Sub-watershed and structure nos.	Flow added	Storage: Water supply	Storage: Water quality control	Annual costs	Drainage area	Year needed	Purpose
	(c.f.s.)	(acre-feet)	(acre-feet)	($/c.f.s.)	(sq. mi.)		
53-49	0.8	234	702	5,320	1.2	1976	WS&QC @ New Windsor; QC @ Union Bridge
53-31A	7.4		6,420	2,560	10.7	1967	QC @ Union Town, Frizzelburg, and Fountain Valley
53-46A	7.8		8,268	4,280	10.6	1984	QC @ Union Bridge and New Windsor
53-7	5.1		4,164	3,785	7.6	2001	QC for downstream reaches
53-12	2.1		1,022	6,635	2.8	2008	" " " "
58-6	2.2		2,340	4,920	3.0	1965	QC @ Sterling
58-9	3.5		3,666	5,360	4.7	1966	QC @ Floris
58-14	5.9		6,162	3,160	7.9	1967	QC @ Arcola
59-2	2.0	594	1,206	3,280	3.0	1971	WS&QC @ Manassas and Dulles Airport area
59-7	1.9	198	402	2,960	6.0	1972	" " " " "
59-9	5.0	1,425	2,895	4,000	7.2	1971	" " " " "
59-11	4.1	1,056	2,144	2,880	6.4	1970	" " " " "
59-13	8.7	2,211	4,489	2,680	13.4	1968	" " " .. "
59-31	2.1	544	1,106	3,520	3.3	1970	" " " " "
59-37	1.0	198	402	4,600	2.0	1972	" " " " "
59-39	5.5	1,049	2,131	2,720	10.6	1969	" " " " "
59-41	6.4	1,650	3,350	1,760	10.0	1967	" " " " "
59-46	14.9	3,287	6,773	1,240	24.9	1967	" " " " "
59-47	9.5	3,140	6,375	2,320	12.2	1968	" " " " "
60-16	8.9	936	8,424	1,840	12.0	1969	WS&QC @ Warrenton-Nokesville-Calverton
60-25	0.9	27	243	2,520	2.7	1972	" " " " "
60-35	5.6	376	3,380	3,320	9.4	1971	" " " " "
60-39	9.5	632	5,688	1,680	15.8	1968	" " " " "
60-42	7.0	476	4,284	2,440	11.9	1970	" " " " "
60-73	11.8	748	6,732	1,440	19.6	1967	" " " " "

Crop and pasture damages were based upon an average level of management defined as that level fully expected to be in common use on most flood plain farms by the year 1985. An analysis based on current yields and prices indicates that the present per acre crop and pasture damages are about 45 percent below those resulting from the predicted future levels of management. Although the composite effect of the projections used could be such as to somewhat overstate present economic losses from flooding, it serves as an indication of conditions when most of the floodwater-retarding structures would be justified. All floodwater-retarding structures have been evaluated by sub-watersheds and have been scheduled to be constructed by 1985.

Table 17 shows the acres of flood plain by use with and without protection.

Table 17 - Estimated Upstream Flood Plain Land Use
With and Without Protection, 1985
Potomac River Basin

Land use	Without protection	With protection
	(acres)	(acres)
Cropland	33,461	38,595
Pasture	53,767	56,644
Woodland and idle	43,406	31,147
Miscellaneous	6,485	10,733
Totals	137,119	137,119

No attempt was made to evaluate what effect the development within the sub-watershed would have on reduction of damages further downstream on the major tributaries or the main stem of the Potomac.

The proposed development for the reduction of flood damages is discussed by sub-watersheds and physiographic regions. Wherever it was possible, multiple purpose dams were selected to provide the needed storage to protect local damage centers and to provide the needed supplemental flow.

Table 18 shows the costs and benefits, including recreational benefits of the development for flood prevention by sub-watersheds.

In the Appalachian Plateau region there are two sub-watersheds

Table 18 - Costs and Benefits, Including Incidental Recreation Benefits, of Flood Prevention Development by Sub-watersheds Potomac River Basin

Sub-watershed no.	Drainage area	Average annual cost	Average annual benefits
	(square miles)	(dollars)	(dollars)
1	77.0	75,640	99,005
3	12.2	7,416	10,508
8	146.3	197,053	285,615
9	38.9	45,884	113,238
10	59.6	72,300	149,889
11	66.6	54,181	135,984
12	38.3	40,345	80,325
19	35.1	31,120	39,872
20	44.8	48,982	67,306
21	118.8	174,048	420,969
* 22	71.8	78,750	142,180
* 23	40.1	29,740	22,919
24	57.2	28,276	41,797
25	28.9	15,814	26,796
26	63.5	38,065	63,745
30	96.9	57,702	131,006
32	22.9	13,774	17,227
33	46.8	56,701	69,500
34	165.8	191,123	258,021
35	128.6	98,328	151,690
36	44.5	47,910	116,801
37	56.3	62,522	118,782
38	34.0	18,171	36,711
39	27.0	16,017	27,914
41	10.4	11,800	30,796
42	9.6	5,840	6,532
44	10.0	13,656	22,277
45	14.8	24,633	54,114
46	97.4	59,577	81,884
51	37.3	53,107	68,449
52	79.1	68,181	147,567
53	77.3	80,204	156,164
58	15.6	13,692	25,314
59	103.3	57,965	127,406
60	123.6	72,080	195,667
68	46.2	37,568	54,713
69	25.0	29,545	90,754
71	20.2	11,562	21,040
74	15.2	28,124	38,128
Totals	2,207.0	2,067,396	3,748,605

* Evaluate as one unit

that will benefit from floodwater storage. They are Wills Creek, sub-watershed No. 1, and North Branch of the Potomac, sub-watershed No. 3.

In the Appalachian Ridges region there are 13 sub-watersheds that will benefit from floodwater storage. They are: Patterson Creek, No. 8; Lunice Creek, No. 9; North Fork of South Branch, No. 10; Upper South Branch, No. 11; Mill Creek, No. 12; Little Cacapon, No. 19; North River, West Virginia, No. 20; Moorefield River, No. 21; Lost River, No. 22; Cacapon River, No. 23; Sleepy Creek, No. 24; Tonoloway Creek, No. 25; and Licking Creek, No. 26.

In Georges Creek, sub-watershed No. 5, an effective flood prevention program on the main stem would require as a minimum 3 inches of runoff retardation from 15,000 acres. No single structure, or combination of structures, above the damage reach has the required capacity except the Midland site. However, this site has severe geologic limitations. There are no significant tributaries on Georges Creek. Therefore, no dams are proposed for development at this time.

In New Creek, sub-watershed No. 6, a flood prevention project has been planned and partially installed under the authority of the Flood Control Act of 1944. The plan includes 12 structures. Eleven are single purpose flood prevention dams, and one multiple purpose structure includes flood prevention and water supply storage for the city of Keyser, West Virginia. Five of these structures are now constructed. The combined land treatment and structural measures for flood prevention will reduce floodwater and sediment damages nearly 37 percent. This benefit, together with more intensive use of the flood plain lands, amounts to an average annual value of about $70,000.

In sub-watershed No. 18, a direct tributary of the Potomac, a flood prevention project for Warm Springs Run has been planned and partially installed under the authority of the Flood Control Act of 1944. The plan includes nine floodwater-retarding structures. Eight of these dams have been constructed. The combined land treatment and structural measures for flood prevention will reduce floodwater and sediment damages nearly 80 percent. This benefit, together with more intensive use of the flood plain lands, amounts to an average annual value of about $19,600.

Studies indicated that the flood prevention development for both New Creek and Warm Springs Run are adequate to meet the needs. Therefore, no additional development was considered for these two sub-watersheds.

In Patterson Creek, sub-watershed No. 8, a program for flood prevention and watershed protection is now being planned under the provisions of the Flood Control Act of 1944. The plan provides for 34 single purpose flood prevention dams and the inclusion of flood prevention in one multiple purpose structure which will store water for Fort Ashby, West Virginia. Collectively, these structures will temporarily

store 25,836 acre-feet of floodwater. The combined land treatment and structural measures will reduce damages within the sub-watershed by 77 percent. This benefit, together with more intensive use of the flood plain, amounts to an average annual value of about $268,000.

In Moorefield River, sub-watershed No. 21, a program for flood prevention and watershed protection has been developed and included in a work plan under the provisions of the Flood Control Act of 1944. The plan provides for 24 single purpose flood prevention dams. However, the comprehensive plan provides for three of these structures to be made multiple purpose to provide water supply and water quality control for the town of Moorefield, West Virginia. Collectively, these structures will temporarily store 25,949 acre-feet of floodwater. The combined land treatment and structural measures will reduce damages within the sub-watershed by 62 percent. This benefit, together with more intensive use of the flood plain, amounts to an average annual value of about $400,000.

Four structures are built and are in operation and two structures are under construction or near completion.

In the Appalachian Valley region there are 13 sub-watersheds that will benefit from floodwater storage. They are Back Creek, No. 30; Lower North Fork Shenandoah, No. 32; Upper North Fork Shenandoah, No. 33; North River, Virginia, No. 34; Middle River, No. 35; South River, No. 36; Upper South Fork Shenandoah, No. 37; Smith Creek, No. 38; Passage Creek, No. 39; Opequon, No. 41; Antietam Creek, No. 42; Lower South Fork Shenandoah, No. 44; and Hawks Bill Creek, No. 45.

On North River, Virginia, sub-watershed No. 34, there have been several watershed work plans developed on parts of the sub-watershed under the Flood Control Act of 1944. The information contained in these work plans was considered in developing the needs for flood prevention in the entire sub-watershed. An economic analysis of the costs and benefits indicates that 12 single purpose flood prevention structures and six multiple purpose dams are needed and justified, including those now in work plans. Collectively, they will temporarily store 31,858 acre-feet of floodwater and will control 38 percent of the sub-watershed, thus providing a reduction of 66 percent of the projected damages.

South River: A watershed work plan was prepared for this sub-watershed under the Flood Control Act of 1944. The work plan proposed 16 flood prevention structures. Eleven of these structures have been built and are now in operation. The information contained in the work plan was considered in developing the needs for flood prevention in the entire sub-watershed. An economic analysis of the costs and benefits indicates that three single purpose flood prevention dams and 11 multiple purpose structures are needed and justified. It is proposed that several of the single purpose flood prevention structures be redesigned for multiple purpose use and they be included in the 11 multiple purpose structures listed above. Collectively, these structures will temporarily

store 9,543 acre-feet of floodwater. They will control 30 percent of the sub-watershed, thus providing a reduction of 73 percent of the projected damages.

In the Piedmont region there are nine sub-watersheds that will benefit from floodwater storage. They are Goose Creek, No. 46; Toms Creek, No. 51; Upper Monocacy, No. 52; Big and Little Pipe Creek, No. 53; Broad Run, No. 58; Bull Run, No. 59; Occoquon Creek, No. 60; Seneca Creek, No. 68; and Rock Creek, No. 69.

In Rock Creek, sub-watershed No. 69, a program for flood prevention and watershed protection is now being planned under the provisions of Public Law 566. The plan provides for two multiple purpose structures which will include storage for recreation and temporary storage for flood prevention. These two will temporarily store 4,790 acre-feet of floodwater and reduce damages in the sub-watershed by 61 percent. The benefits accruing to these dams amount to an average annual value of $61,500 from the flood damage reduction.

In the Coastal Plain region there are two sub-watersheds that will benefit from floodwater storage. They are Zekiah Swamp-Gilbert Run, No. 74, and St. Mary's River, No. 71.

The Gilbert Run tributary, sub-watershed No. 74, has been planned under the authority contained in Public Law 566. The plan consists of three single purpose floodwater-retarding structures and some channel improvements. The average annual benefits that will accrue to the structural measures amount to about $34,500.

Table 19 shows the average annual flood damages by types in the upstream areas of the basin.

Table 19 - Summary of Average Annual Flood Damages by Types for the Upstream Areas Potomac River Basin

Agricultural:	
Crop and pasture	$1,745,000
Minor improvements	245,000
Sub-total	$1,990,000
Non-agricultural:	
Major improvements	$ 828,000
Roads and bridges	977,000
Indirect damages	316,000
Sub-total	$2,121,000
Total	$4,111,000

24. RECREATION BENEFITS

The experience of the Department of Agriculture has been that wherever water has been impounded it will be used for recreational purposes regardless of whether it has been specifically planned for recreational use.

It is unnecessary to cite statistics demonstrating the need for water-based recreational facilities or the number of users visiting such impoundments after they have been developed. Whether the people are urban or rural dwellers, water acts as a magnet; most people show a strong desire for water-oriented recreation.

Barring a radical change in the circumstances of our national life, it is reasonable to assume that individual and group demands for such recreational facilities and services will be at least as strong in the future as they are today. More important, however, is the sum-total of the demand. The projected total demand will become many times greater as the population grows and such conditions as the spread of leisure time, levels of personal income, and the mobility of the public improves.

In the past several decades there has been increasing recreational use of reservoir waters. Sherando Lake in the George Washington National Forest serves as an example. The availability of water for recreation in such areas that previously had little to offer served a tremendous need. Other developments have experienced similar use, and this is particularly significant because many of these reservoirs were built for other purposes.

Recreational use will be made of these reservoirs constructed for water supply and water quality control and the sediment pools for flood prevention dams. None of the construction costs have been allocated to recreational use, nor provisions made for additional facilities for this use.

However, benefits from the recreational use of these reservoirs were evaluated by the National Park Service and the Fish and Wildlife Service.

For the upstream structures the National Park Service developed the criteria for computing the recreation benefits other than fishing, and the Fish and Wildlife Service developed criteria for computing the fishing benefits. Each agency prepared an interim report to the Department of Agriculture setting forth the assumptions and procedures to be used in estimating the recreation and fishing benefits to be allocated to these projects.

The interim report prepared by the National Park Service gave its views as to the value of the recreational use of these pools, as follows:

"The value of $1.60 per visitor-day, used by the National Park

Service in evaluation of recreation at major water control projects, is based upon the value of the total recreation activities and experiences that may be enjoyed at a water control project. This covers a full range of recreation activities including boating, water skiing, camping, picnicking, swimming, hiking, and interpretive facilities available in an atmosphere of big water.

"Boating, water skiing, interpretive services, and probably hiking can be ruled out as probable activities. This leaves swimming, picnicking, and possibly camping, especially on National Forests, as the most likely activities. The quality of the water puts considerable doubt on the probability of acceptable swimming conditions. Without swimming, the sites seem to offer little inducement to visitation, except for hunting and fishing. An adjusted value, therefore, of $.75 per visitor-day has been assigned as an average visitor-day benefit. This is comparable to the data regarding fees charged for various activities in the Agricultural Research Service's publication, Fish, Wildlife and Other Recreational Benefits of Small Reservoirs in Arkansas, Kentucky, and Maryland."

In an interim report prepared by the Fish and Wildlife Service, the net value per man-day at a single purpose fishing lake was set at $1.00. The net value per man-day at a flood prevention, water supply, and multiple purpose reservoir was set at $.75.

The Fish and Wildlife Service's interim report presents its views on the value of fishing use of these impoundments, as follows:

"The unit value assigned to fisherman-use in the two types of impoundments were based on the Report of the Panel on Recreational Values on a Proposed Interim Schedule of Values for Recreational Aspects of Fish and Wildlife, approved by the Subcommittee on Evaluation Standards, Interagency Committee on Water Resources, in October 1960.

"The monetary values given above do not encompass all recreational values of the fishery resource but represent a judgment estimate of net values of recreational fishing."

The criteria set forth by both the National Park Service and the Fish and Wildlife Service were used to arrive at the estimated combined recreational benefits allocated to each sub-watershed. The combined estimated recreational benefits accruing to 406 structures proposed for other uses amount to $889,000 annually.

While this incidental benefit is significant, actual experience in the recreational use being made of water stored in existing upstream structures in the basin indicates that there will be much greater participation in all water-oriented sports than is predicted by the use of the above criteria, except perhaps water skiing. This will be especially true of swimming. It appears, therefore, that the estimated recreational

benefits based on National Park Service criteria are very conservative.

In addition to the incidental benefits provided by the dams selected to meet the other needs, a number of structures were included for single purpose recreation reservoirs or for recreation as a multiple purpose use with flood prevention. All but two of these dams are located on National Forest land in Physiographic Region Three.

Two single purpose reservoirs in Upper North Fork Shenandoah, sub-watershed No. 33, have a combined storage of 1,079 acre-feet and a surface area of 64 acres. In Middle River, sub-watershed No. 35, two single purpose recreational reservoirs have a combined storage of 1,300 acre-feet and provide a total surface area of 35 acres. In Upper South Fork Shenandoah, sub-watershed No. 37, three structures have a combined storage of 2,368 acre-feet and surface area of 98 acres. In Passage Creek, sub-watershed No. 39, the two single purpose reservoirs and one multiple purpose structure have a combined storage of 1,677 acre-feet for recreational use and a surface area of 111 acres. The two remaining structures are in Rock Creek, sub-watershed No. 69. They are multiple purpose in use and are presently being planned for inclusion in a work plan developed under the provisions of Public Law 566.

25. PROJECT DESIGN CRITERIA

Generalized hydrologic and structural design criteria were developed as guides in planning and estimating the costs of the upstream projects. These criteria, together with the physical data obtained from topographic maps and field investigations, are considered adequate for the preliminary designs and cost estimates. The final design and analysis in connection with the preparation of detailed construction plans will require more specific criteria and detailed data on conditions prevailing at the individual sites.

Storage requirements. The structures are designed to provide storage for three basic purposes: (1) sediment storage, (2) conservation storage, and (3) flood prevention or floodwater-retarding storage. The lower portion of the pool is used for the accumulation of sediment anticipated to be delivered over a 50-year period. Until this portion of the pool is filled with sediment, the water occupying the space is available for some other beneficial use. Above the sediment pool, permanent storage is provided for water supply, water quality control, recreation, or other beneficial uses. The top of this permanent pool will set the elevation of the crest of the principal spillway. Flood-retarding storage is provided between the crest of the principal spillway and the crest of the emergency spillway.

The allowance for sediment storage was made on the basis of a yield of 1/2 inch from the drainage area over a 50-year period. Consideration of the nature of the stream gradient, sediment particle size, and other

factors indicate that about 85 percent of the sediment trapped will be deposited within the limits of the sediment pool and the remaining 15 percent will be deposited elsewhere within the overall physical limits of the reservoir.

The capacity designated as conservation storage includes the provision for supplemental flows for water supply; water quality control; and for recreation, including fishing and hunting. This type of storage is provided for uses that involve long-term impoundment of waters and has its greatest potential value when fully occupied. The conservation storage capacity was fixed by a generalized relationship of the ultimate storage potential, based upon the topographic features and limits at the site and the water yield from the drainage area. The demand curve for the respective physiographic regions was used to compute the 3-year refill rate of the conservation pool at each structure.

For those reservoirs where water supply or water quality control was the only project purpose, space was provided to temporarily store 3 additional inches of runoff from the drainage area. This represents the runoff from a 50-year frequency storm. It was concluded that it would be less costly to allow sufficient storage above the water supply pool so that vegetated spillways would not be used more frequently than once in 50 years than it would be to construct concrete spillways to pass the storm water.

Flood prevention storage provides for short-term impoundment of surplus floodwaters and has its greatest potential value when unoccupied. Flood prevention storage capacity was provided to adequately regulate the design flood without discharge through the emergency spillway, assuming the sediment and conservation pools filled at the beginning of the design storm and assuming the flood regulating outlet, or principal spillway, to be fully operative during the period of flood impoundment. Estimates of the hydrograph for the design flood were based on regionalized rainfall and runoff criteria. Regionalized precipitation values were determined in accordance with rainfall estimates published by the U. S. Weather Bureau. Maximum precipitation amounts for a 100-year frequency storm over a 25-square mile area are 4.15 inches for 3 hours, 5.28 inches for 6 hours, 6.38 inches for 12 hours, and 7.50 inches for 24 hours. The runoff associated with these amounts of precipitation varies with the antecedent moisture and soil-cover conditions. It was assumed that throughout the typical area the 5-day antecedent rainfall would range from 0.5 inch to 1.5 inches. The percentage of runoff, based on weighted soil-cover complexes and average antecedent moisture conditions, was found to range from 75 to 85 percent. Using a 6-hour storm period with the above conditions, the 100-year frequency flood runoff would have a volume of about 4.2 inches. This flood routed through the structure, assuming the regulating outlet to be operative, would require a storage volume slightly less than 4 inches of runoff from the controlled area without discharge through the emergency spillway. Initial appraisals of the floodwater storage capacity of the upstream structures were adopted as being equivalent to a

volume of at least 4 inches of runoff from the drainage area.

Principal spillway capacities. Outlets considered in the planning of upstream structures fall into two general categories. These are: (1) a gated outlet for the release of water supply and supplemental flow, and (2) an ungated flood-regulating outlet. The first type is required in a single purpose water supply reservoir for regulating releases for downstream use or in a multiple purpose structure as a separate water supply-regulating outlet. The flood-regulating outlet is required in a single purpose flood prevention dam or in a multiple purpose project where flood prevention is one of the project purposes. In the case of a multiple purpose structure, both types may be installed in the riser and discharged through a common outlet.

Outlet capacities for the release of the conservation storage normally are based on the water demands downstream. For planning purposes these release rates for the upstream structural measures were based on the yield-storage relationship for each individual structure.

In structures containing storage for flood prevention, the design capacities for flood-regulating outlets were selected by taking into consideration the time required to empty the flood pool. Stage-discharge curves were developed for each site, based on the size of pipe needed to empty the flood pool in a 5-day period beginning at the cessation of flood runoff.

Emergency spillway capacities. The flood flows used in computing emergency spillway capacities were based on general storm phenomena and probable maximum precipitation data supplied by the U. S. Weather Bureau.

The hydrograph selected for estimating the emergency spillway discharge, adjusted in accordance with the flood storage available and the discharge rate through the principal spillway, is termed the "spillway design hydrograph." In establishing the spillway design hydrograph to be used to proportion the emergency spillways of upstream dams, consideration was given to three conditions of flood plain development, as follows:

(1) Between 20 and 30 percent of the probable maximum 6-hour precipitation should be used where downstream reaches are limited to woodland, open farmland, and secondary rural roads. This type of use results in low damage potential.

(2) Between 30 and 50 percent of the probable maximum 6-hour precipitation should be used where the proposed sites are some distance above human habitation and where the development in the flood plain consists of farm buildings (exclusive of homes), public utilities, main highways, and minor railroads. This type of use results in average damage potential.

(3) Between 50 and 70 percent of the probable maximum 6-hour precipitation should be used where damage potential is high. This would involve urban or suburban habitation in downstream reaches and high average property

damages consisting of homes, industrial and commercial buildings, major through ways, and mainline railroads.

Moisture condition II, or average moisture conditions, is used in all three cases.

Freeboard requirements for the upstream dams were based on a 6-foot minimum height above the crest of the emergency spillway. The spillways were proportioned to provide maximum stage of approximately 3 feet above the emergency spillway control section when routing the spillway design flood through the flood pool, assuming the initial water level in the flood pool be that reached by a 5-day drawdown through the principal spillway following a 50-year frequency flood. Three feet of additional freeboard were provided above the maximum flood pool stage created by the spillway design storm to prevent damage from wave overtopping and as an additional factor of safety.

Pool area. The pool area required will be the area inundated at an elevation 3 feet above the crest of the emergency spillway. The area up to the elevation of the crest of the principal spillway riser will be cleared of trees and brush. It was considered that roads and utilities in the reservoir area would need to be raised or relocated.

Structural criteria for dam. The elevation of the top of the dam was taken as the maximum pool elevation plus 3 feet of additional freeboard, as described above. It was assumed the available material for the earth embankment would be properly graded to obviate the use of special impervious core. The side slopes of 3 on 1 upstream and 2.5 on 1 downstream were adopted as generally acceptable for earth embankments, which will be protected from erosion by seeding to adapted grasses or by riprapping at vulnerable points. Figures 8 through 12 give detailed structural design for a multiple purpose dam.

Structural criteria for spillways. Principal spillways are to be designed as reinforced concrete risers in the pool and a precast pipe or monlithic conduit through the dam at streambed level. The conduit size will be large enough to carry the design release rate plus the average low flow in the stream immediately above the dam, but in no case less than 24 inches in diameter. The riser in the pool is designed with an anti-vortex device and a gate to permit low flow releases and draining the pool. Figures 13 through 16 show details for spillways for a multiple purpose structure.

The vegetated emergency spillways are designed as a broad-crested weir of sufficient width to pass the required spillway design flood. They are constructed in earth for critical velocities not to exceed the permissible velocity for the soil at the site and the vegetation to be established. For higher velocities, reinforced concrete is to be used in construction unless the spillway is excavated in rock. The earth spillway will not be brought into operation until a storm occurs which exceeds a 50- or 100-year frequency, depending upon the design criteria

used for the particular structure.

26. ESTIMATES OF COSTS AND BENEFITS

Estimates of costs. The large number of upstream structural measures under consideration required a simplified procedure for making initial cost estimates of each structure as a basis for identifying those worthy of further consideration and to avoid unnecessary examination of those dams which would lack economic justification or would result in excessive storage costs. The estimating procedure had to be applicable for use with only limited data available for any specific site. The intended use also made it necessary that the procedures take advantage of some generalizations. The derived cost estimates were based on the design criteria discussed in the preceding paragraphs.

The cost estimates for individual sites assumed normal construction costs where average conditions of development existed in the protected flood plain area and where it was practical to impound sufficient flood prevention storage to permit the use of a sod-lined emergency spillway. For sites upstream from reaches with high damage potential, or where concrete-lined spillways would be needed, estimates were made separately based on designs embodying greater structural safety.

Cost estimates for structures that had water supply or water quality control storage as a project purpose were made, allowing for the cost of providing sufficient storage above the water supply pool to temporarily store 3 inches of runoff from the drainage area. In the estimating of the first cost the storage was in lieu of providing for the construction of a concrete spillway.

The first cost of the structure was based on the sum of the following four items of costs:

(1) cost of dam and principal and emergency spillways (including 20 percent contingencies)

(2) seeding and fencing

(3) engineering and administration -- 25 percent of (1) and (2)

(4) lands and relocations costs

After determination of the estimated first cost, the estimated annual equivalent cost was computed as 4 percent of the total first cost. This provided for interest, amortization, and operation and maintenance.

Estimates of benefits. Benefits expected to accrue to the proposed plan of development result from: (1) provisions of immediate and future water supply storage for use in the upstream area, (2) water stored for water quality control, (3) reduction of flood plain damages and enhancement of flood plain lands, and (4) new or improved recreational facilities.

POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P # 14
MULTIPLE-PURPOSE DAM
for
WATER SUPPLY FOR THE CITY OF KEYSER & FLOOD PREVENTION

DRAINAGE AREA	3242. Acres
TOTAL STORAGE	1944. Acre Ft.
FLOOD WATER RETARDING STORAGE	844. Acre Ft.
WATER SUPPLY STORAGE	960. Acre Ft.
WATER SURFACE AREA	37. Acres
HEIGHT OF DAM	93. Feet
VOLUME OF FILL	670,700. Cubic Yards

BUILT UNDER THE WATERSHED PROTECTION AND FLOOD PREVENTION ACT
by
CITY OF KEYSER
and
POTOMAC VALLEY SOIL CONSERVATION DISTRICT
with the assistance of
SOIL CONSERVATION SERVICE
of the
U. S. DEPARTMENT OF AGRICULTURE
1962

TABLE OF CONTENTS

POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P # 14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
COVER SHEET

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed HOLLAND MAY '62 Date J.V. RISZDORFER, KESSEL, JULY '62	Approved by Title HEAD, E & WP UNIT
Drawn GEO. MERCER JULY '62	Harold M Rhodes Title STATE CONSERVATION ENG'R
Traced	
Checked SMALL KESSEL, HOLLAND, RIDDER, Aug '62	Figure 8

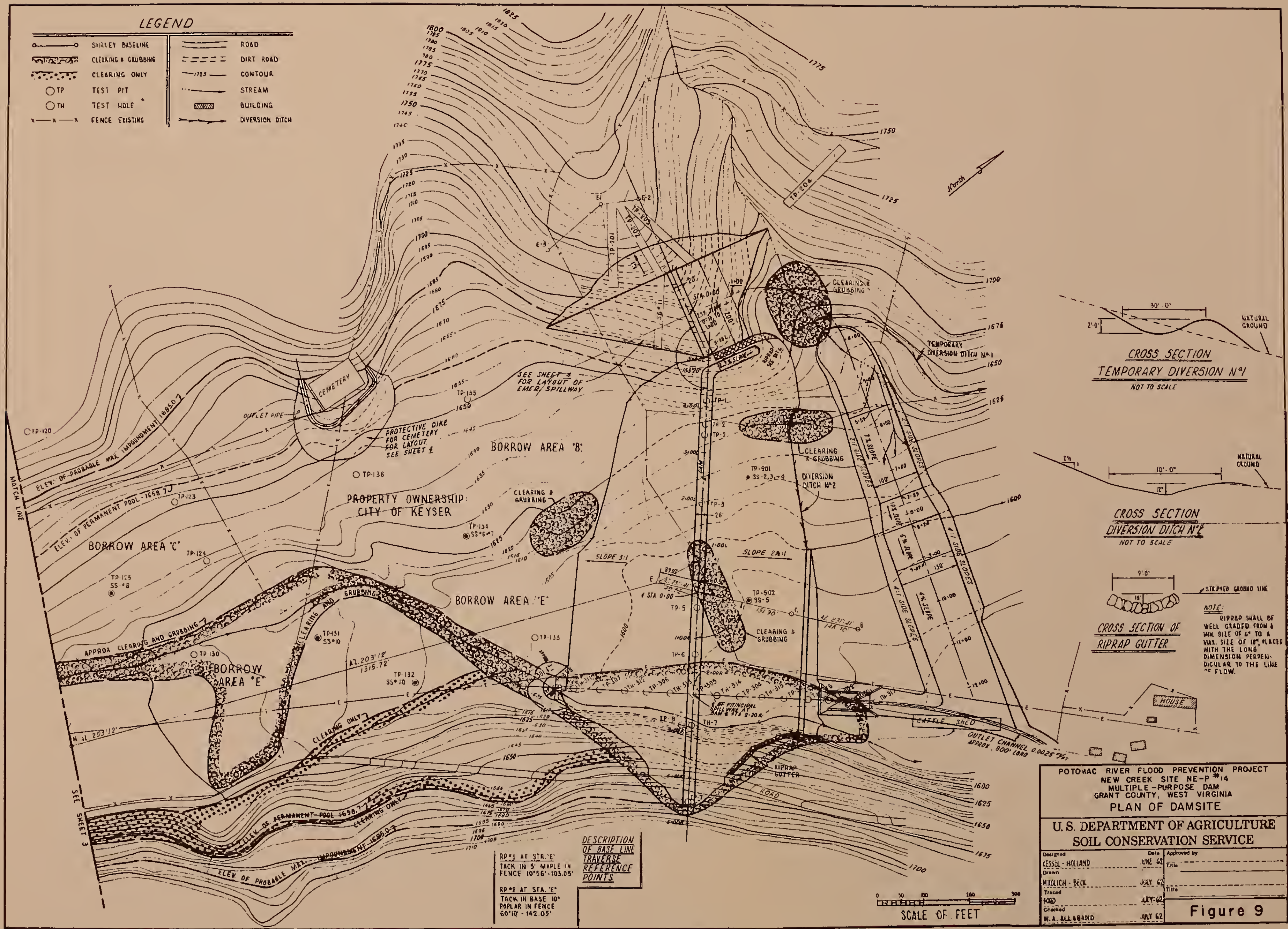
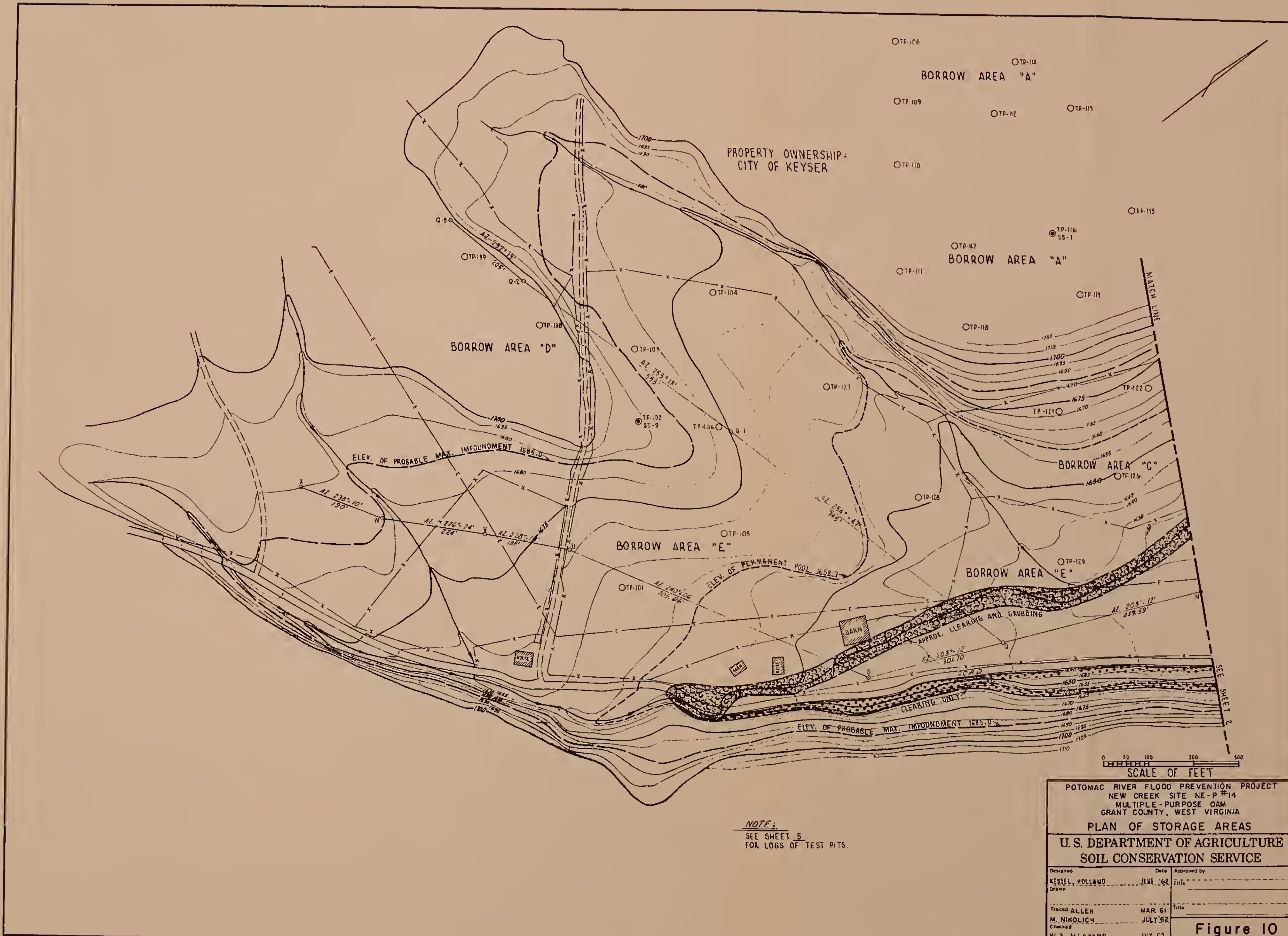

LEGEND
SURVEY BASELINE
CLEARING & GRUBBING
CLEARING ONLY
TP TEST PIT
TH TEST HOLE
FENCE EXISTING
ROAD
DIRT ROAD
CONTOUR
STREAM
BUILDING
DIVERSION DITCH
North
CEMETERY
OUTLET PIPE
PROTECTIVE DIKE FOR CEMETERY FOR LAYOUT SEE SHEET 4
SEE SHEET 4 FOR LAYOUT OF EMER. SPILLWAY
BORROW AREA "B"
BORROW AREA "C"
BORROW AREA "E"
PROPERTY OWNERSHIP: CITY OF KEYSER
ELEV. OF PROBABLE MAX. IMPOUNDMENT 1685.0
ELEV. OF PERMANENT POOL 1658.7
APPROX. CLEARING AND GRUBBING
CLEARING AND GRUBBING
CLEARING ONLY
TEMPORARY DIVERSION DITCH No 1
DIVERSION DITCH No 2
SLOPE 3:1
SLOPE 2½:1
2:1 SIDE SLOPES
4:1 SIDE SLOPES
RIPRAP GUTTER
OUTLET CHANNEL APPROX. 800' LONG 0.0025 Ft/Ft
CATTLE SHED
HOUSE
ROAD
MATCH LINE
SEE SHEET 3
CROSS SECTION TEMPORARY DIVERSION No 1
NOT TO SCALE
NATURAL GROUND
CROSS SECTION DIVERSION DITCH No 2
NOT TO SCALE
CROSS SECTION OF RIPRAP GUTTER
STRIPPED GROUND LINE
NOTE: RIPRAP SHALL BE WELL GRADED FROM A MIN. SIZE OF 6" TO A MAX. SIZE OF 18", PLACED WITH THE LONG DIMENSION PERPENDICULAR TO THE LINE OF FLOW.
DESCRIPTION OF BASE LINE TRAVERSE REFERENCE POINTS
RP #1 AT STA. "E" TACK IN 5' MAPLE IN FENCE 10°56' - 103.05'
RP #2 AT STA. "E" TACK IN BASE 10" POPLAR IN FENCE 60°10' - 142.05'
SCALE OF FEET
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P #14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
PLAN OF DAMSITE
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed KESSEL - HOLLAND JUNE 62
Drawn NIKOLICH - BECK JULY 62
Traced FORD JULY 62
Checked W. A. ALLABAND JULY 62
Approved by

Figure 9


BORROW AREA "A"
PROPERTY OWNERSHIP:
CITY OF KEYSER
BORROW AREA "A"
MATCH LINE
BORROW AREA "D"
ELEV. OF PROBABLE MAX. IMPOUNDMENT 1686.0
BORROW AREA "C"
BORROW AREA "E"
ELEV. OF PERMANENT POOL 1658.7
BORROW AREA "E"
APPROX. CLEARING AND GRUBBING
BARN
CLEARING ONLY
ROAD
ELEV. OF PROBABLE MAX. IMPOUNDMENT 1685.0
SEE SHEET 2
SCALE OF FEET
NOTE:
SEE SHEET 5
FOR LOGS OF TEST PITS.
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P #14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
PLAN OF STORAGE AREAS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed KESSEL, HOLLAND JUNE '62
Traced ALLEN MAR 61
M. NIKOLICH JULY '62
Checked W. B. ALLABAND JULY 62
Figure 10

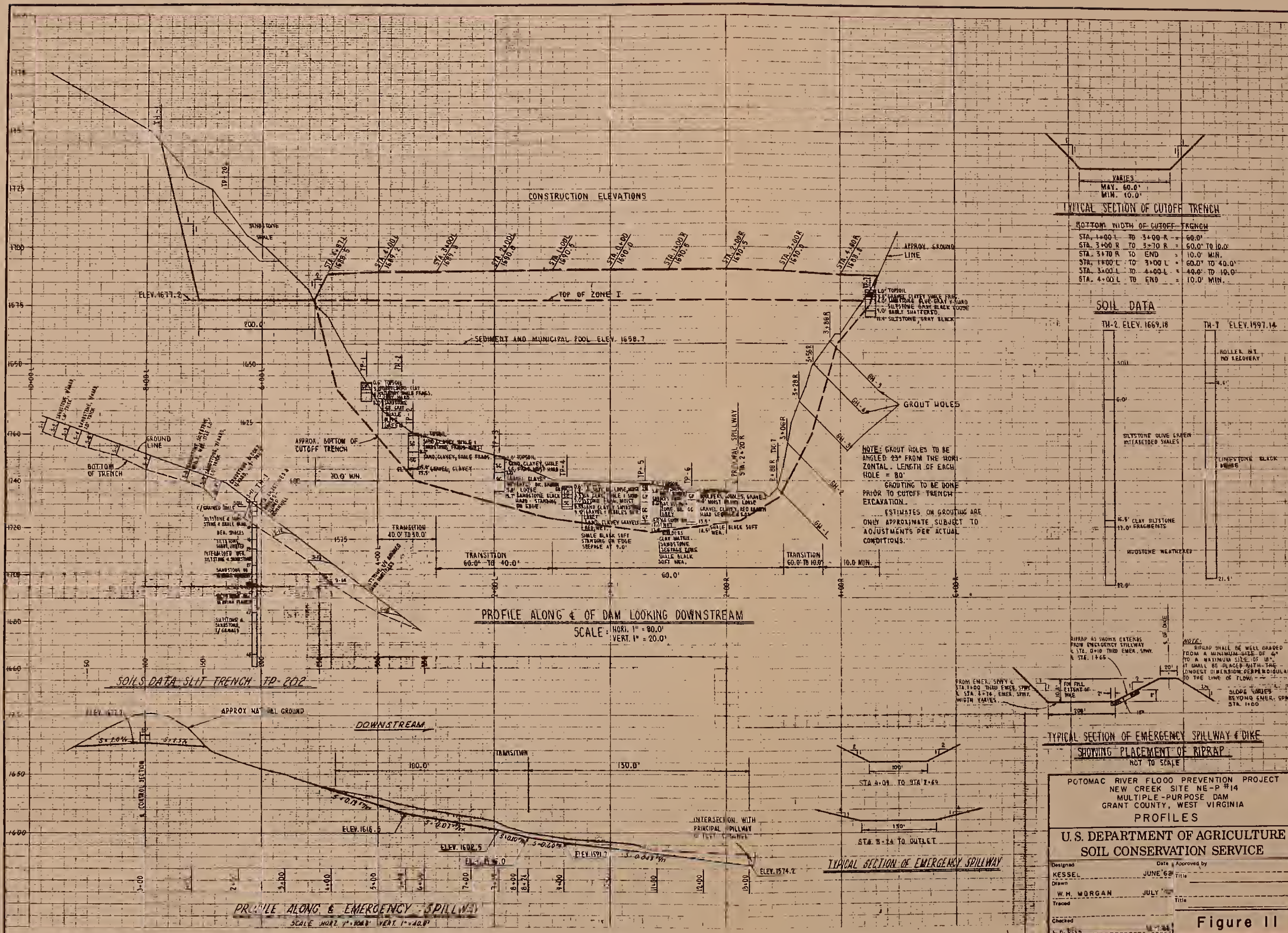

CONSTRUCTION ELEVATIONS
TOP OF ZONE I
ELEV. 1677.2
200.0'
SEDIMENT AND MUNICIPAL POOL ELEV. 1658.7
APPROX. GROUND LINE
GROUT HOLES
APPROX. BOTTOM OF CUTOFF TRENCH
GROUND LINE
BOTTOM OF TRENCH
20.0' MIN.
TRANSITION 40.0' TO 60.0'
TRANSITION 60.0' TO 40.0'
TRANSITION 60.0' TO 10.0'
10.0 MIN.
60.0'
PRINCIPAL SPILLWAY
NOTE: GROUT HOLES TO BE ANGLED 23° FROM THE HORIZONTAL. LENGTH OF EACH HOLE = 80'
GROUTING TO BE DONE PRIOR TO CUTOFF TRENCH EXCAVATION.
ESTIMATES ON GROUTING ARE ONLY APPROXIMATE SUBJECT TO ADJUSTMENTS PER ACTUAL CONDITIONS.
PROFILE ALONG ℄ OF DAM LOOKING DOWNSTREAM
SCALE: HORI. 1" = 80.0' VERT. 1" = 20.0'
SOILS DATA SLIT TRENCH TP-202
VARIES
MAX. 60.0'
MIN. 10.0'
TYPICAL SECTION OF CUTOFF TRENCH
BOTTOM WIDTH OF CUTOFF TRENCH
STA. 1+00 L TO 3+00 R = 60.0'
STA. 3+00 R TO 3+70 R = 60.0' TO 10.0'
STA. 3+70 R TO END = 10.0' MIN.
STA. 1+00 L TO 3+00 L = 60.0' TO 40.0'
STA. 3+00 L TO 4+00 L = 40.0' TO 10.0'
STA. 4+00 L TO END = 10.0' MIN.
SOIL DATA
TH-2 ELEV. 1669.18
TH-7 ELEV. 1597.14
TYPICAL SECTION OF EMERGENCY SPILLWAY & DIKE SHOWING PLACEMENT OF RIPRAP
NOT TO SCALE
APPROX NATURAL GROUND
DOWNSTREAM
TRANSITION
100.0'
150.0'
ELEV. 1616.5
ELEV. 1602.5
ELEV. 1591.7
ELEV. 1574.2
INTERSECTION WITH PRINCIPAL SPILLWAY
STA 4+09 TO STA 7+69
STA 8+24 TO OUTLET
TYPICAL SECTION OF EMERGENCY SPILLWAY
PROFILE ALONG ℄ EMERGENCY SPILLWAY
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P #14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
PROFILES
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed KESSEL
Drawn W.H. MORGAN

Figure 11

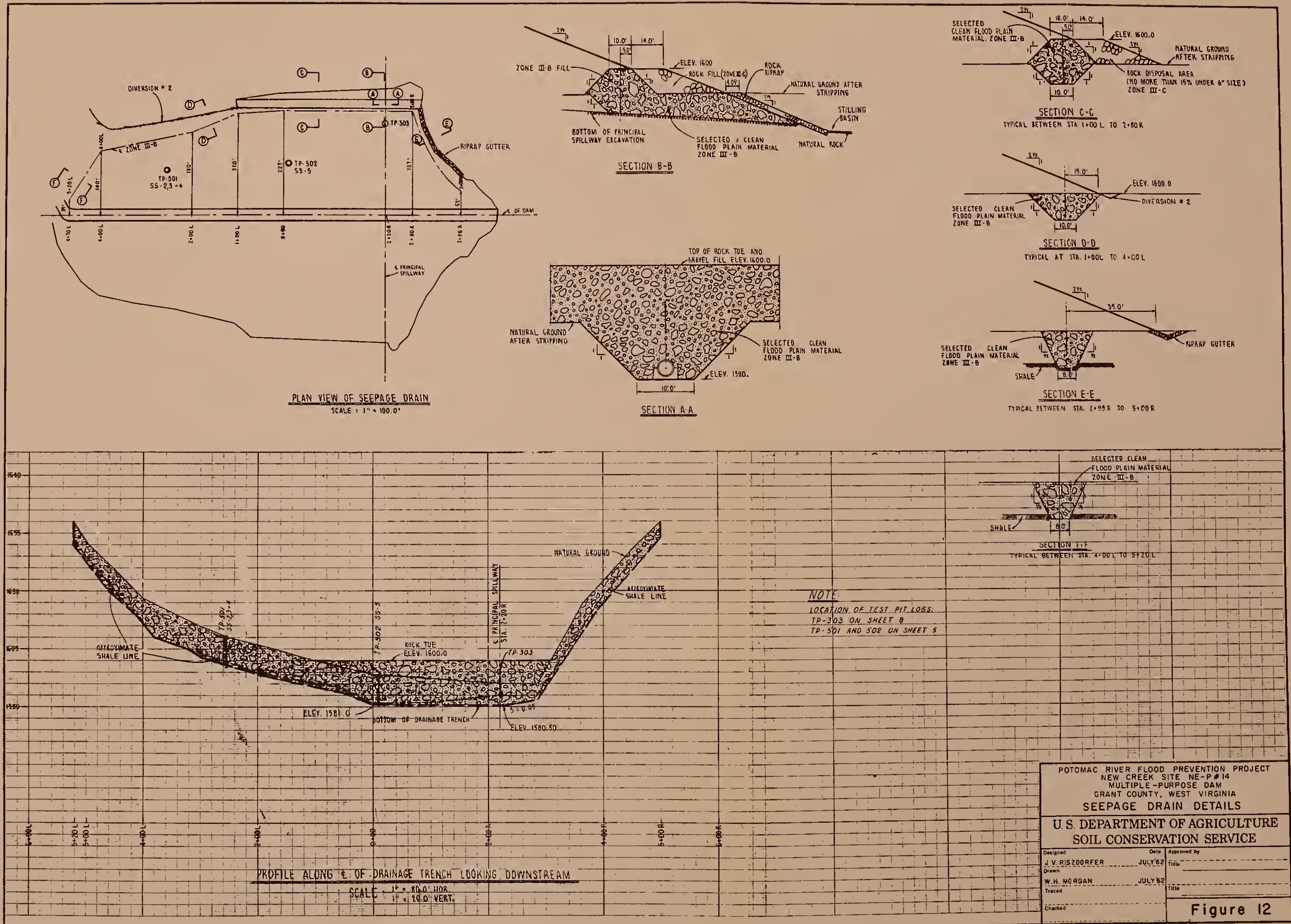
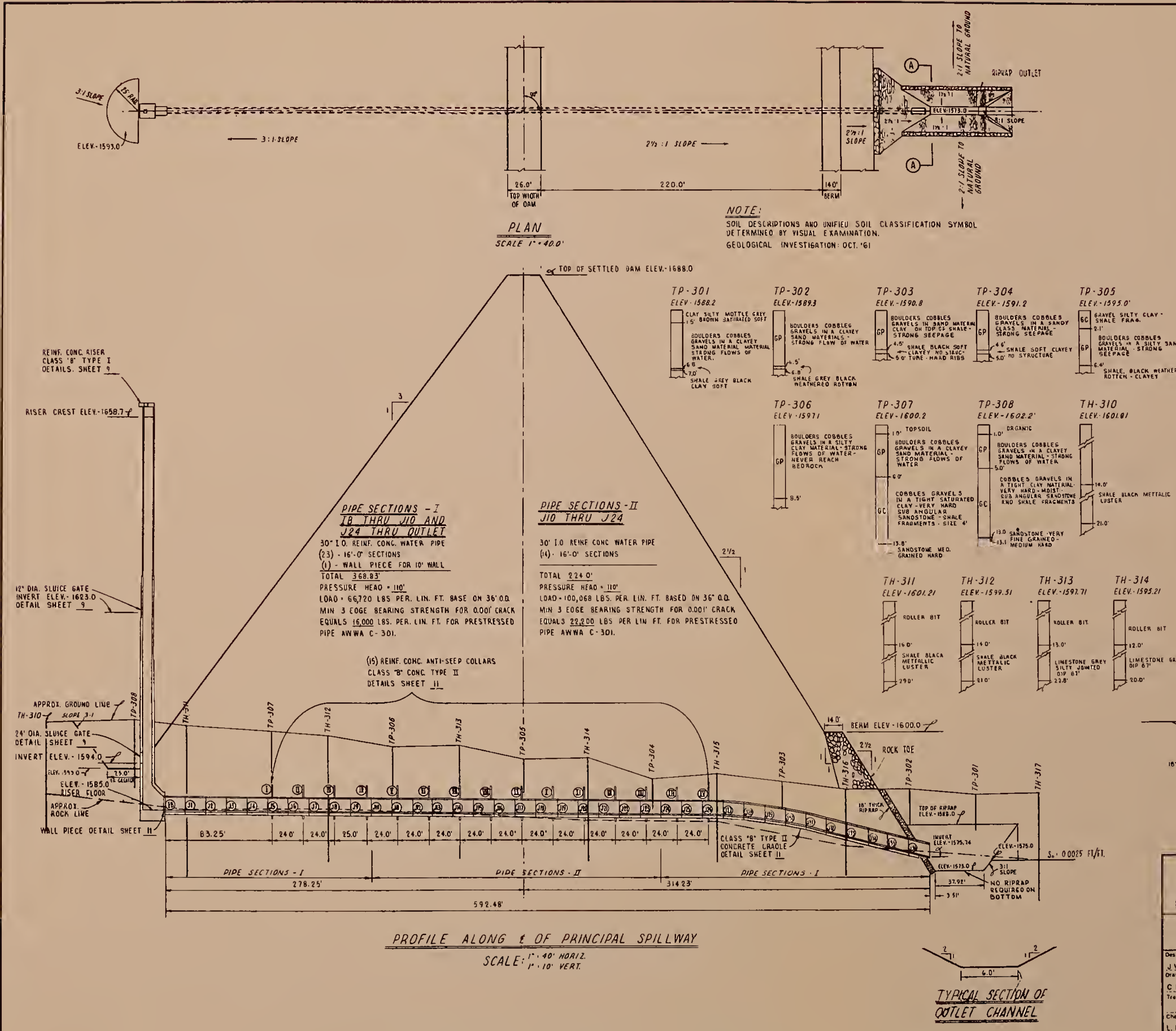

PLAN VIEW OF SEEPAGE DRAIN
SCALE : 1" = 100.0'
DIVERSION # 2
ZONE III-B
TP-501
SS-2,3-4
TP-502
SS-5
TP-303
RIPRAP GUTTER
℄ OF DAM
℄ PRINCIPAL SPILLWAY
ZONE III-B FILL
ELEV. 1600
ROCK FILL (ZONE III-C)
ROCK RIPRAP
NATURAL GROUND AFTER STRIPPING
STILLING BASIN
BOTTOM OF PRINCIPAL SPILLWAY EXCAVATION
SELECTED & CLEAN FLOOD PLAIN MATERIAL ZONE III-B
NATURAL ROCK
SECTION B-B
TOP OF ROCK TOE AND GRAVEL FILL ELEV. 1600.0
NATURAL GROUND AFTER STRIPPING
SELECTED CLEAN FLOOD PLAIN MATERIAL ZONE III-B
ELEV. 1580.
SECTION A-A
SELECTED CLEAN FLOOD PLAIN MATERIAL, ZONE III-B
ELEV. 1600.0
NATURAL GROUND AFTER STRIPPING
ROCK DISPOSAL AREA (NO MORE THAN 15% UNDER 6" SIZE) ZONE III-C
SECTION C-C
TYPICAL BETWEEN STA 1+00 L TO 2+80 R
ELEV. 1600.0
DIVERSION # 2
SELECTED CLEAN FLOOD PLAIN MATERIAL ZONE III-B
SECTION D-D
TYPICAL AT STA. 1+00 L TO 4+00 L
RIPRAP GUTTER
SELECTED CLEAN FLOOD PLAIN MATERIAL ZONE III-B
SHALE
SECTION E-E
TYPICAL BETWEEN STA. 2+95 R TO 5+00 R
SELECTED CLEAN FLOOD PLAIN MATERIAL ZONE III-B
SHALE
SECTION F-F
TYPICAL BETWEEN STA. 4+00 L TO 5+20 L
NATURAL GROUND
APPROXIMATE SHALE LINE
APPROXIMATE SHALE LINE
ROCK TOE ELEV. 1600.0
℄ PRINCIPAL SPILLWAY STA. 2+20 R
TP-303
ELEV. 1581.0
BOTTOM OF DRAINAGE TRENCH
S = 0.05
ELEV. 1580.50
NOTE:
LOCATION OF TEST PIT LOGS:
TP-303 ON SHEET 8
TP-501 AND 502 ON SHEET 5
PROFILE ALONG ℄ OF DRAINAGE TRENCH LOOKING DOWNSTREAM
SCALE : 1" = 80.0' HOR.
1" = 20.0' VERT.
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P # 14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
SEEPAGE DRAIN DETAILS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed J. V. RISZOORFER JULY '62
Drawn W. H. MORGAN JULY '62
Traced
Checked
Approved by
Title

Figure 12



DESIGN				AS BUILT		
POINT	DISTANCE FROM RISER WALL PIECE	INVERT ELEV. OF 30" PIPE	SLOPE	INVERT PIPE ELEVATION	GAP TOP	GAP BOTTOM
I 8	0	1585.00	0.0022 ′/′			
J 1	16	1584.96				
J 2	32	1584.93				
J 3	48	1584.89				
J 4	64	1584.86				
J 5	80	1584.82				
J 6	96	1584.79				
J 7	112	1584.75				
J 8	128	1584.72				
J 9	144	1584.68				
J10	160	1584.64				
J11	176	1584.61				
J12	192	1584.57				
J13	208	1584.54				
J14	224	1584.50				
J15	240	1584.47				
J16	256	1584.43				
J17	272	1584.40				
J18	288	1584.36				
J19	304	1584.32				
J20	320	1584.29				
J21	336	1584.25				
J22	352	1584.22				
J23	368	1584.18				
J24	384	1584.15				
J25	400	1584.11				
J26	416	1584.08				
J27	432	1584.04				
J28	448.03	1583.79	0.0146			
J29	464.06	1583.36	0.0270			
J30	480.09	1582.73	0.0394			
J31	496.12	1581.90	0.0518			
J32	512.15	1580.87	0.0644 ′/′			
J33	528.15	1579.85				
J34	544.15	1578.82				
J35	560.15	1577.79				
J36	576.15	1576.76				
OUTLET	592.48	1575.74				

I	83.25	1584.81	
II	107.25	1584.76	
III	131.25	1584.71	
IV	156.25	1584.66	
V	180.25	1584.60	
VI	204.25	1584.55	
VII	228.25	1584.49	
VIII	252.25	1584.44	
IX	276.25	1584.38	
X	300.25	1584.32	
XI	324.25	1584.27	
XII	348.25	1584.21	
XIII	372.25	1584.16	
XIV	396.25	1584.12	
XV	420.25	1584.07	

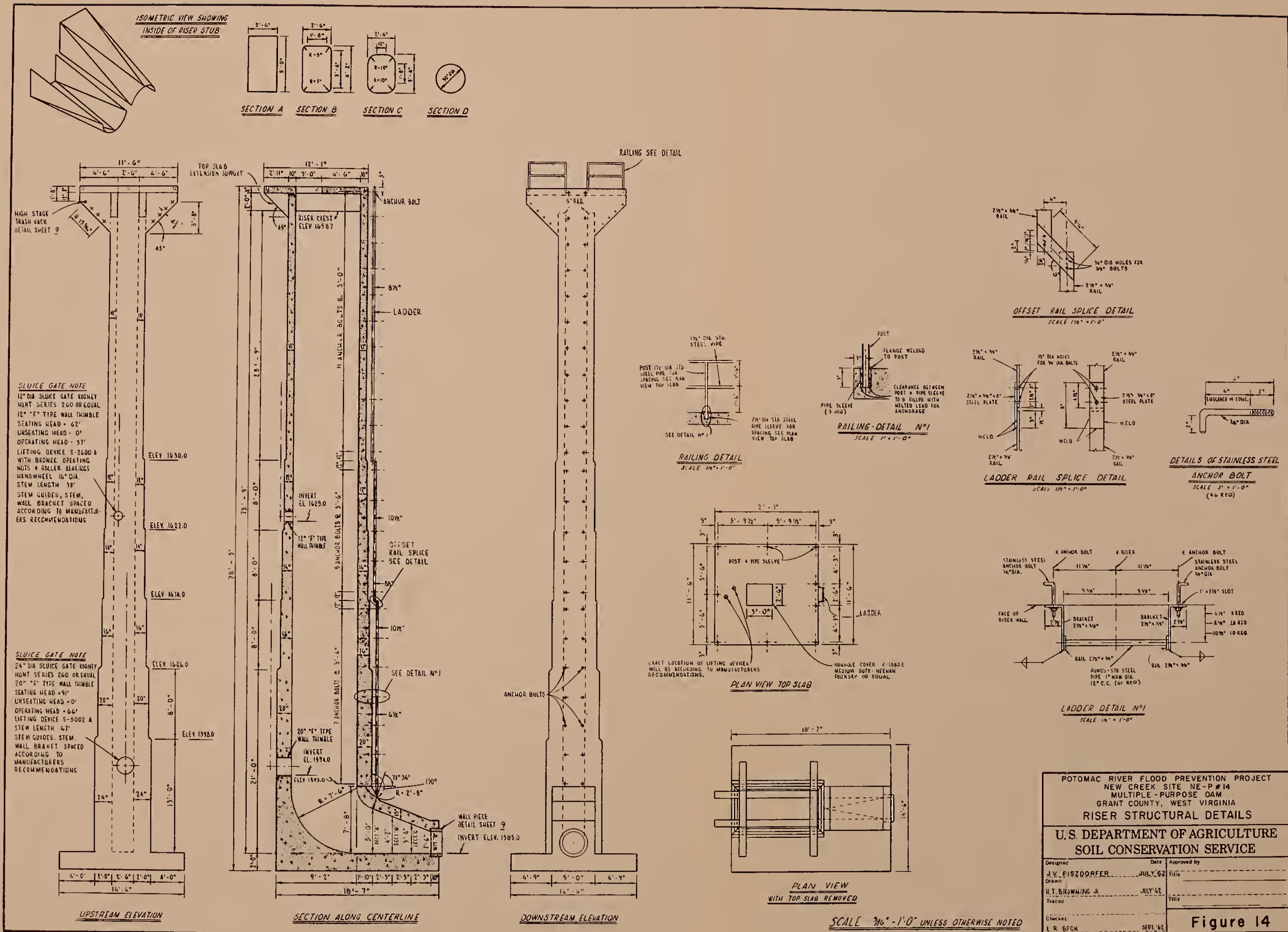
NOTE:
ABOVE DIMENSIONS FOR LENGTHS OF PIPE ARE NOMINAL AND DO NOT INCLUDE CREEP.

POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P #14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
PLAN-PROFILE OF PRINCIPAL SPILLWAY

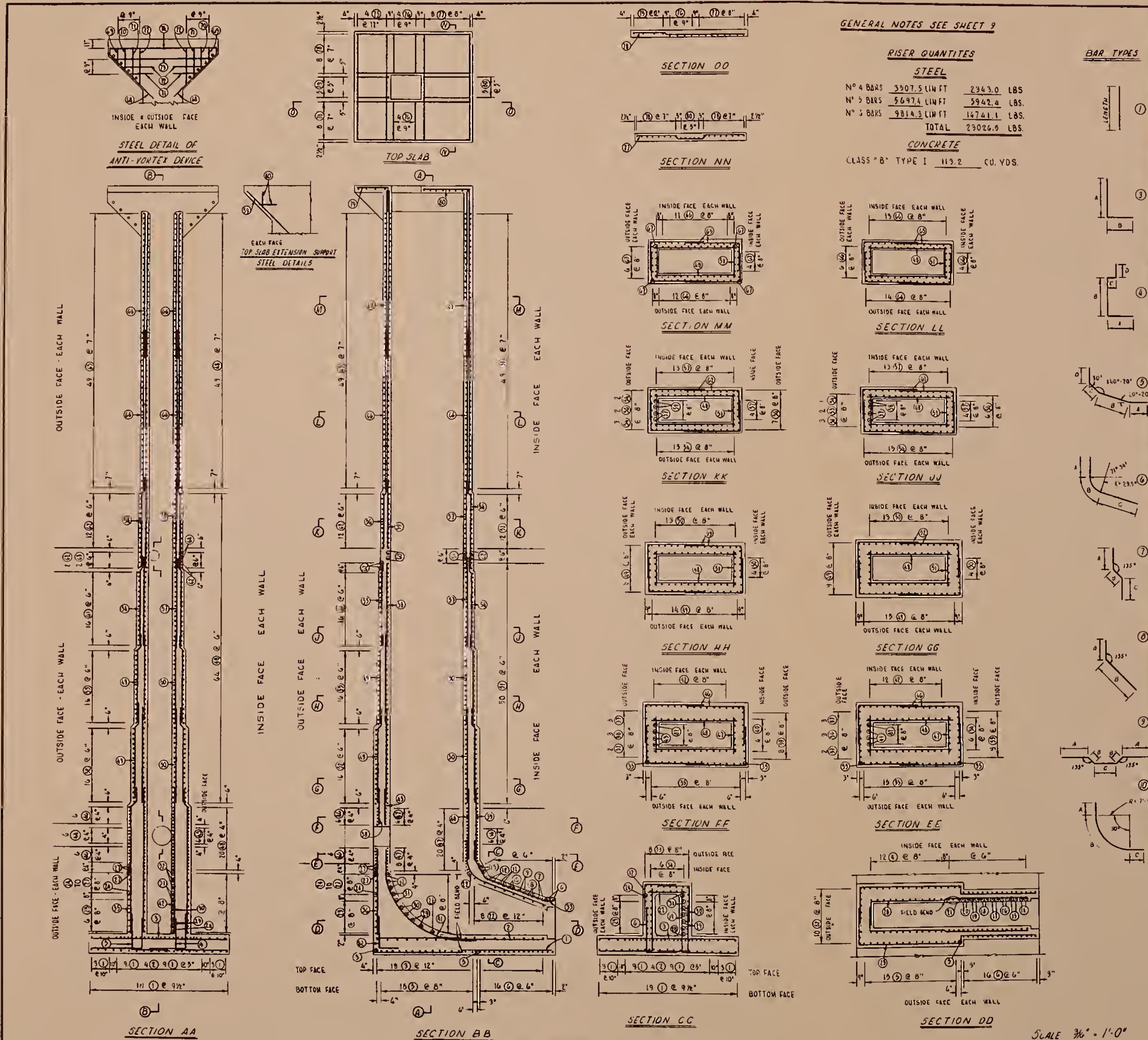
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed HOLLAND	MAY '62	Approved by
J.V. RISZDORFER	JULY '62	Title
Drawn C.B. FORD	JULY '62	Title
Traced		
Checked L. A. BECK	SEPT. '62	

Figure 13



ISOMETRIC VIEW SHOWING INSIDE OF RISER STUB
SECTION A
SECTION B
SECTION C
SECTION D
UPSTREAM ELEVATION
SECTION ALONG CENTERLINE
DOWNSTREAM ELEVATION
RAILING SEE DETAIL
OFFSET RAIL SPLICE DETAIL
RAILING DETAIL
RAILING - DETAIL Nº1
LADDER RAIL SPLICE DETAIL
DETAILS OF STAINLESS STEEL ANCHOR BOLT
PLAN VIEW TOP SLAB
LADDER DETAIL Nº1
PLAN VIEW WITH TOP SLAB REMOVED
SCALE 3/16" - 1'-0" UNLESS OTHERWISE NOTED
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P # 14
MULTIPLE - PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA
RISER STRUCTURAL DETAILS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Figure 14



GENERAL NOTES SEE SHEET 9

RISER QUANTITES

STEEL

N° 4 BARS	3307.5	LIN FT	2343.0	LBS
N° 5 BARS	5697.4	LIN FT	5942.4	LBS.
N° 6 BARS	9814.3	LIN FT	14741.1	LBS.
		TOTAL	23026.5	LBS.

CONCRETE

CLASS "B" TYPE I 113.2 CU. YDS.

STEEL SCHEDULE

MARK	LOCATION	QUAN	SIZE	LENGTH	TYPE	A	B	C	D	TOTAL FT.
1	RISER	43	6	18-3	1					784.75
2		6	4	17-3	1					69.00
3		19	5	14-0	1					266.00
4		24	5	8-11	1	3-4	5-7			214.00
5		32	6	7-9	3	4-0	3-9			248.00
6		36	5	6-9	1	3-6	3-3			243.00
7		4	5	7-4	3	4-1	3-3			29.33
8		4	5	7-5	3	4-2	3-3			29.67
9		4	5	7-10	3	4-7	3-3			31.33
10		4	5	8-2	3	4-11	3-3			32.67
11		4	5	8-6	3	5-8	3-3			34.00
12		4	5	8-11	3	5-8	3-9			35.67
13		4	5	10-0	3	6-9	3-3			40.00
14		4	5	11-2	3	5-7	5-7			44.67
15		4	5	11-7	3	6-0	5-7			46.33
16		4	5	11-11	3	6-4	5-7			47.67
17		4	5	12-4	3	6-9	5-7			49.33
18		4	5	12-8	3	7-1	5-7			50.67
19		4	5	13-0	3	7-5	5-7			52.00
20		4	5	13-4	3	7-9	5-7			53.33
21		6	5	14-7	3	9-0	5-7			87.50
22		9	5	4-0	1					36.00
						A	B	C	D	
23		12	6	22-10	4	3-10	10-6	0-9	7-9	274.00
24		2	6	20-3	6	4-0	10-6	0-9	5-0	40.50
25		2	4	18-3	4	4-0	10-6	0-9	3-0	36.50
26		2	6	16-3	4	4-0	10-6	0-9	1-0	32.50
27		6	6	14-6	3	4-0	10-6			87.00
28		2	4	13-6	3	11-3	2-3			27.00
29		6	6	14-9	3	12-6	2-3			59.00
30		4	6	16-3	3	14-0	2-3			65.00
31		4	6	15-6	3	13-3	2-3			62.00
32		6	6	11-9	3	9-6	2-3			70.50
						A	B	1	D	
33		8	6	11-6	5	0-9	6-6	2-3	2-0	92.00
34		4	6	12-1	6	2-0	3 1	7-0		72.50
35		34	6	15-6	7	13-0	0-6	2-0		527.00
36		3	6	8-9	1					26.25
37		5	6	15-6	1					77.50
38		3	6	4-3	1					12.75
39		4	4	7-0	1					56.00
40		6	5	7-0	1					42.00
41		3	5	15-5	10	1-3	12-2	2-0		46.25
42		25	5	15-3	1					381.25
43		3	5	4-3	1					12.75
44		6	6	8-3	3	2-0	6-3			49.50
45		6	6	7-9	3	1-6	6-3			46.50
46		60	6	10-3	1	4-0	6-3			615.00
47		34	5	4-0	1					136.00
48		266	6	4-0	1					2394.00
49		92	5	10-1	7	4-0	0-6	1-7		927.67
50		68	5	10-0	1					680.00
51		224	4	4-0	1					896.00
52		64	4	9-11	3	6-2	3-9			634.67
53		64	6	9-2	3	5-9	3-5			586.67
54		78	5	9-10	7	8-0	0-3	1-7		766.74
55		2	5	8-10	7	8-0	0-3	0-7		17.67
56		2	5	7-7	7	5-9	0-3	1-7		15.17
57		64	5	10-0	1					640.00
58		2	5	8-6	1					17.00
59		6	5	7-3	1					43.50
60		10	4	1-9	1					17.50
61		64	4	9-0	3	5-9	3-3			576.00
62		58	6	8-8	3	5-7	3-1			502.67
63		1	4	6-2	1	5-7	0-7			12.33
64		2	6	7-5	7	5-7	1-10			14.83
65		196	4	8-4	3	5-5	2-11			1633.25
66		120	4	15-9	1					1890.00
67		28	4	18-3	1					511.00
68	ANTI-VORTEX	8	5	7-3	8	0-9	6-6			58.00
69		4	5	1-6	1					12.00
70		8	5	2-3	1					18.00
71		16	5	3-0	1					48.00
72		16	5	3-9	1					60.00
73		4	5	10-0	1					40.00
74		4	5	11-0	1					44.00
75	TOP SLAB	4	4	11-0	1					44.00
76		8	4	4-0	1					32.00
77		8	4	11-6	9	4-0	0-6	2-6		92.00
78		16	5	11-10	7	3-4	0-4	8-2		189.33
79		5	6	5-10	3	2-6	3-4			29.17
80		5	4	5-0	1					25.00
81	RISER	1	5	21-5	10	7-3	12-2	2-0		21.42
82		10	5	5-9	3	3-4	2-5			57.50

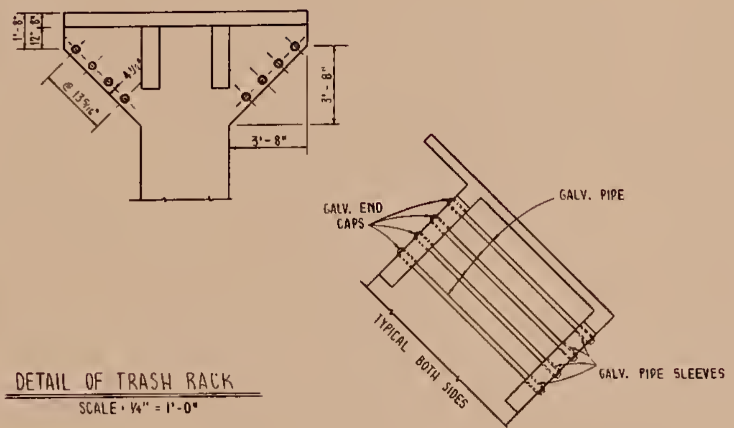
POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P #14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA

RISER STEEL LAYOUT

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

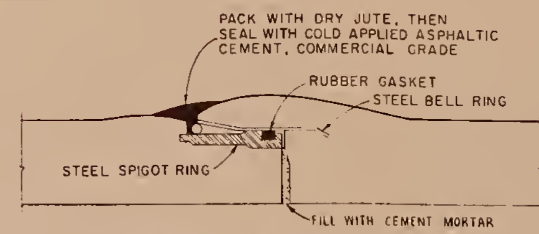
Designed	Date	Approved by
J.V. RISZDORFER	JULY '62	Title
Drawn		
H.T. BROWNING JR.	JULY '62	Title
Traced		
Checked L.R. BECK	SEPT. '62	
J.V. RISZDORFER	JULY '62	

Figure 15

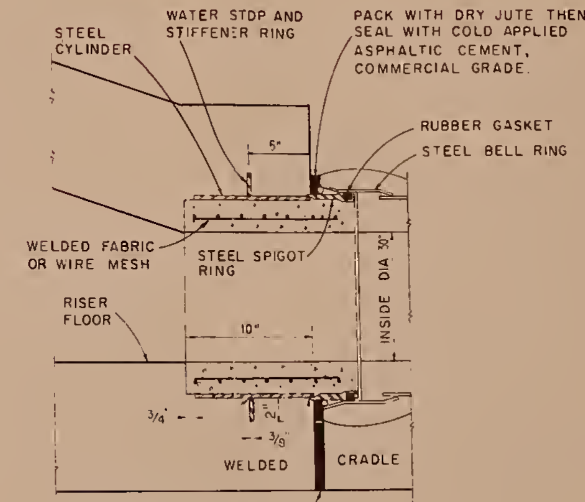


DETAIL OF TRASH RACK

SCALE: ¼" = 1'-0"



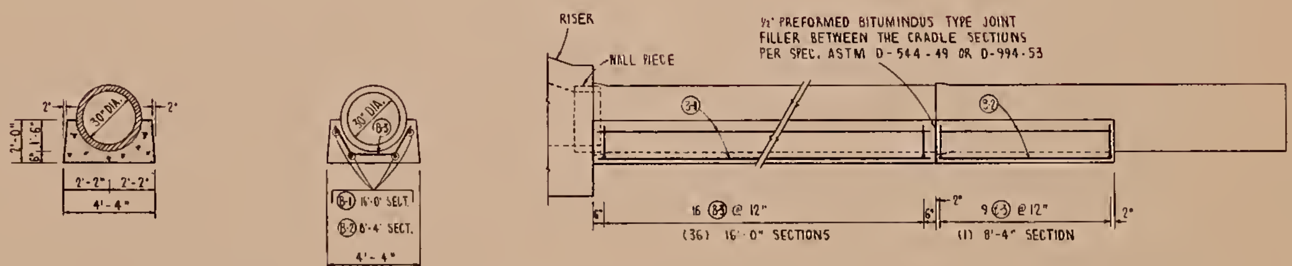
DETAIL OF REINFORCED CONCRETE WATER PIPE JOINT



DETAIL OF WALL PIECE IN RISER

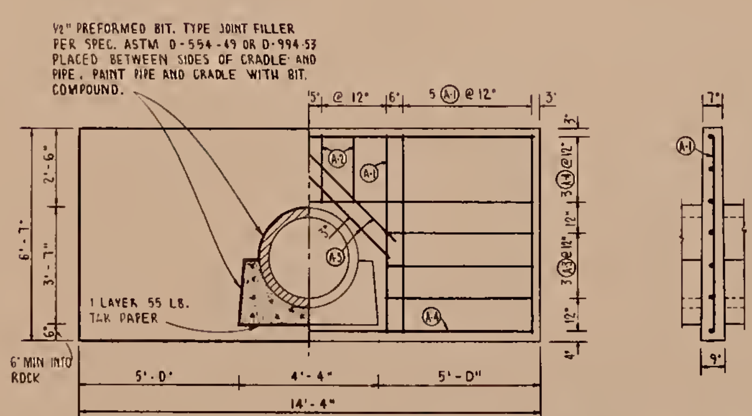
GENERAL NOTES

1 - ALL CONCRETE SHALL BE CLASS "3" AND OF THE TYPE NOTED ON SHEET 8.
2 - PORTLAND CEMENT TYPE I WITH AN AIR ENTRAINING ADMIXTURE OR TYPE IA SHALL BE USED.
3 - ALL REINFORCING STEEL TO BE LAPPED A MIN OF 30 BAR DIAMETERS
4 - ALL REINFORCING STEEL PLACED IN CONCRETE POURED AGAINST THE GROUND SHALL HAVE A MIN OF 3" CLEAR COVER WHERE FORMS ARE USED BARS SHALL HAVE A MIN OF 2" CLEAR COVER
5 - ALL EXPOSED EDGES OF CONCRETE TO HAVE A ¾" CHAMFER
6 - ALL METAL FAB. NOT GALVANIZED TO BE PAINTED SPEC. WVA 14-58



DETAIL OF REINFORCED CONCRETE CRADLE

SCALE: ¼" = 1'-0"



DETAIL OF REINFORCED CONCRETE ANTI-SEEP COLLAR

(15 REQUIRED)

SCALE: ⅜" = 1'-0"

STEEL SCHEDULE

MARK	LOCATION	QUAN.	SIZE	LENGTH	TYPE	A	B	C	TOTAL FT.
A-1	COLLAR (15)	180	4	6 - 3	1				1125.00
A-2	"	60	4	2 - 3	1				135.00
A-3	"	150	4	4 - 6	1				675.00
A-4	"	60	4	4 - D	1				240.00
B-1	CRADLE	144	4	15 - 6	1				223[illegible].00
B-2	"	4	4	8 - 2	1				[illegible].67
B-3	"	585	4	5 - 0	2	1-6	2-D	1-6	2925.00

BAR TYPES

QUANTITIES THIS SHEET ONLY

REINF. STEEL

NO. 4 BAR 7964.67 LIN. FT. 5320.39 LBS

CONCRETE

CLASS "B" TYPE II 134.3 CU. YDS.

BILL OF MATERIAL

LOCATION	ITEM	SIZE	LENGTH	QUANTITY
TRASH RACK	GALV PIPE STD. STR. THREADED ENDS	3" DIA.	9'-6"	8
	GALV END CAPS	3" DIA.		16
	GALV. PIPE SLEEVES	3½" DIA.	0'-10"	16
	WASHERS	3½" DIA.		16

POTOMAC RIVER FLOOD PREVENTION PROJECT
NEW CREEK SITE NE-P # 14
MULTIPLE-PURPOSE DAM
GRANT COUNTY, WEST VIRGINIA

CRADLE - COLLAR - TRASH RACK - MISC. DETAILS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	J.V. RISZDORFER	JULY '62	Approved by
Drawn	W.H. MORGAN	JULY '62	Title
Traced			
Checked	L.R. BECK	SEPT. '62	

Figure 16

The water supply benefits would accrue from increased quantities and quality of water made available as the result of the installation of the proposed structures in the plan discussed earlier under Water Supply and Water Quality Development. These benefits were assumed to be equal to the costs. This procedure was in lieu of measuring the benefits as the cost of obtaining the same quantity and quality of water by the cheapest alternative means that would most likely be developed by the potential water users in place of the proposed reservoir. In most instances the alternative means would be another structure in the sub-watershed.

An order of merit was established for each reservoir based on the cost per cubic foot per second of supplemental flow. By using the more efficient structures and assuming a benefit-cost ratio of 1.0 to 1.0, the results were somewhat more conservative than would result in using the cheapest alternative means. This would result in claiming as benefits the cost of the cheapest alternative structure or group of structures needed to supply the demand. Assigning monetary benefits to the water supply and water quality development made it possible to compare the potential benefits of storage in the upstream reservoirs and in major reservoirs to determine possible alternates or additions required to meet the overall basin water needs.

The flood prevention benefits were based on reductions of flood plain damages and more intensive use of the flood plain that would result from the construction of the proposed plan of improvements. The damage reduction benefits were determined as the difference between the estimated average annual damages with and without the proposed projects. Land use projections were made for two conditions: (1) use expected to be made of the flood plain lands if no flood prevention project were installed, and (2) expected use of the flood plain lands with a flood prevention project installed. All projections were made in percentage of the flood plain land expected to be in the following uses: (1) crops, (2) pasture, (3) woodland and idle, and (4) other. In some instances it was necessary to sub-divide the cropland into truck or other specialty crops and those such as hay, corn, and small grain in support of the livestock enterprises. The land use projections prepared by the Economic Research Service and present land use determined from the field reconnaissance data were used as a guide. Other data used in making the projections include the population projections and urban expansion estimated to occur by 2010, the expected level of agricultural stability, and the level of protection that the structural program would provide. In most cases it was assumed that the rural non-farm development would be relatively uniform throughout the basin.

The estimated total average annual flood prevention benefits within a sub-watershed were considered as one evaluation unit. Therefore, the benefit-cost ratio applies to the combined costs and benefits accruing to the structures proposed.

Recreational benefits expected to accrue from the proposed water resource development plan were evaluated by the National Park Service and the Fish and Wildlife Service. The evaluation criteria were discussed previously.

In addition to the benefits evaluated, there will be certain intangible benefits which are not susceptible to direct monetary evaluation. Benefits to the general welfare, economy, and security of the people of the basin cannot be pre-determined, nor evaluated in monetary terms.

Table 20 gives the total first cost, average annual equivalent cost, and benefits by project purpose for the upstream structural measures proposed in the plan for the water resource development of the basin. The incidental recreation benefits are included with the other project purposes.

Table 20 - Total First Costs, Average Annual Equivalent Costs, and Average Annual Benefits for Upstream Structural Measures Potomac River Basin

Project purpose	First cost	Average annual costs 1/	Average annual benefits
Flood prevention	$ 51,684,900	$2,067,400	$3,748,600
Water supply	8,748,500	349,900	463,200
Water quality control	42,340,200	1,693,600	1,874,800
Recreation	1,981,300	79,300	94,000
Totals	$104,754,900	$4,190,200	$6,180,600

1/ Includes O&M.

27. SUMMARY OF THE PLAN FOR UPSTREAM STRUCTURAL MEASURES

Table 21 summarizes the pertinent data for the 418 upstream structures included in the plan. The data as presented are for each individual structure, totals for the sub-watersheds, and a grand total for the basin. Figure 17 shows the location and the project purpose of each individual structure. The map is folded in the back cover pocket.

Table 21 - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation				Surface Area				Total Storage					First Cost				
		Flood plain	Top sediment pool	Top conservation pool	Spillway crest	Sediment pool	Conservation pool	Flood prev. pool	Maximum pool	Sediment	Water supply	Water quality control	Flood prev.	Recreation	Water supply	Water quality control	Flood prev.	Recreation	Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 1 - Wills Creek (Pennsylvania and Maryland)																			
1-11	3.0	1,600	1,621		1,645	7		33	39	80			560				51,150		51,150
1-13	7.4	1,680	1,700		1,730	25		58	74	198			1,380				225,450		225,450
1-19	14.8	1,840	1,862		1,885	35		160	180	395			2,760				153,700		153,700
1-25	10.3	1,825	1,850		1,884	23		84	88	275			1,921				85,100		85,100
1-34	2.5	1,880	1,898		1,918	12		30	33	67			466				50,000		50,000
1-37	7.2	2,020	2,049		2,085	16		65	70	192			1,343				210,875		210,875
1-42	7.3	1,500	1,518		1,535	33		90	100	195			1,361				99,750		99,750
1-45	8.7	1,440	1,481		1,496	28		220	275	232			1,623				308,625		308,625
1-51	4.8	1,160	1,199		1,232	10		34	38	128			895				313,500		313,500
1-52	3.1	1,270	1,290		1,317	15		40	43	83			578				145,825		145,825
1-53	7.9	1,735	1,755		1,798	22		53	55	211			1,473				247,025		247,025
Totals 11	77.0					226		867	995	2,056			14,360				1,891,000		1,891,000
Sub-watershed No. 3 - North Branch of Potomac (Maryland and West Virginia)																			
3-41	4.1	2,370	2,394		2,419	10		38	41	109			765				55,925		55,925
3-45A	8.1	2,410	2,433		2,481	14		55	59	216			1,511				129,475		129,475
Totals 2	12.2					24		93	100	325			2,276				185,400		185,400
Sub-watershed No. 8 - Patterson Creek (West Virginia)																			
8-1	3.0	1,170	1,183		1,209	8		42	57	59			566				132,500		132,500
8-2	2.7	1,138	1,151		1,179	7		38	43	49			450				110,700		110,700
8-3	2.7	1,103	1,115		1,138	7		30	34	47			470				125,900		125,900
8-4	7.7	1,088	1,107		1,148	11		78	84	106			1,295				209,400		209,400
8-6	2.1	1,690	1,718		1,754	3		29	34	28			311				186,500		186,500
8-10	3.7	1,637	1,656		1,688	6		36	41	48			581				178,100		178,100
8-12	8.7	930	952		995	11		85	89	130			1,631				215,800		215,800
8-13	6.9	957	983		1,031	10		43	46	120			1,174				275,000		275,000
8-14	1.5	880	896		927	3		14	16	27			244				97,200		97,200
8-15	17.8	838	857		910	19		266	304	201			3,589				490,100		490,100
8-20	1.6	938	953		982	4		13	16	30			250				87,800		87,800
8-21	5.2	920	936		970	9		56	60	69			1,017				172,000		172,000
8-22	2.9	787	801		834	7		28	31	47			549				123,200		123,200
8-23	2.6	933	947		981	5		25	27	34			467				124,800		124,800
8-24	1.1	748	759		778	3		15	17	18			163				48,400		48,400
8-25	1.1	722	735		755	3		14	15	21			166				76,200		76,200
8-26	1.7	735	749		773	4		25	27	29			273				94,900		94,900
8-27	1.1	711	723		743	3		14	16	18			170				65,300		65,300
8-28	6.6	805	813		841	13		90	105	79			1,182				109,500		109,500

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 8 (continued)																			
8-30	1.5	770	785		814	3		14	16	24			222				71,200		71,200
8-31	2.3	698	713		739	5		27	31	34			416				98,300		98,300
8-32	3.4	692	705		736	6		34	37	41			606				107,600		107,600
8-36	1.0	703	713		733	3		12	16	16			136				52,300		52,300
8-37	3.0	692	704		730	7		34	45	48			575				100,200		100,200
8-38	3.4	679	693		722	7		39	47	52			554				97,400		97,400
8-41	27.9	1,055	1,075		1,131	22		172	180	258			4,908				700,000		700,000
8-43	1.9	850	867		897	4		19	21	34			320				101,400		101,400
8-44	1.2	635	646		665	5		18	22	23			221				76,700		76,700
8-45	0.6	628	637		654	2		8	9	11			87				54,400		54,400
8-46	1.7	682	-	721	739	-	14	19	21	31	184		376		60,200		113,925		174,125
8-47	0.7	795	805		820	2		9	11	11			85				37,600		37,600
8-48	1.7	888	900		927	5		20	25	31			312				76,900		76,900
8-49	2.3	1,133	1,147		1,165	7		36	41	43			310				91,100		91,100
8-50	11.0	609	623		659	17		125	140	163			2,025				177,400		177,400
8-52	1.0	717	727		744	3		15	18	17			135				46,600		46,600
Totals 35	145.3					234	14	1,542	1,742	1,997	184		25,836		60,200		4,926,325		4,986,525
Sub-watershed No. 9 - Lunice Creek (West Virginia)																			
9-3	7.3	1,005	1,025		1,055	19		70	78	195			1,361				151,000		151,000
9-6A	4.7	1,015	1,023		1,049	25		75	80	125			877				46,250		46,250
9-12A	19.3	1,195	1,221		1,275	25		128	140	515			3,600				350,000		350,000
9-22A	3.4	1,700	1,724	1,743	1,773	-	16	29	35	90		300	499			49,400	210,600		260,000
9-24A	4.2	1,775	1,798		1,842	12		26	28	112			783				389,250		389,250
Totals 5	38.9					81	16	328	361	1,037		300	7,120			49,400	1,147,100		1,196,500
Sub-watershed No. 10 - North Fork of South Branch (West Virginia)																			
10-10A	22.8	2,145	2,190		2,253	36		104	108	609			4,252				877,500		877,500
10-17	8.8	1,710	1,745		1,793	18		53	56	235			1,641				265,000		265,000
10-49A	18.8	2,985	3,027		3,090	24		96	102	502			3,506				415,000		415,000
10-52A	9.2	2,570	2,597		2,632	26		76	81	246			1,715				250,000		250,000
Totals 4	59.6					104		329	347	1,592			11,114				1,807,500		1,807,500
Sub-watershed No. 11 - South Branch of Potomac River (West Virginia)																			
11-39	12.2	2,200	2,232		2,286	18		71	76	326			2,275				240,000		240,000
11-43	4.8	1,870	1,898		1,941	11		32	34	128			895				180,150		180,150
11-48A	16.5	2,205	2,226		2,256	49		167	182	441			3,077				187,525		187,525

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 11 (continued)																			
11-55	8.7	2,290	2,320		2,348	23		90	100	232			1,623				171,000		171,000
11-70	13.4	2,620	2,646		2,674	31		123	136	358			2,499				145,000		145,000
11-78	6.5	2,660	2,685		2,712	16		65	74	174			1,212				282,500		282,500
11-80A	4.5	2,585	2,612		2,651	10		31	34	120			839				148,350		148,350
Totals 7	66.6					158		579	636	1,779			12,420				1,354,525		1,354,525
Sub-watershed No. 12 - Mill Creek (West Virginia)																			
12-12	22.2	1,155	1,182		1,227	22		220	240	593			4,140				499,500		499,500
12-19	2.0	1,020	1,047		1,085	5		21	24	53			373				100,325		100,325
12-21	1.4	1,140	1,165		1,206	5		12	14	37			261				219,300		219,300
12-23	7.1	1,305	1,320		1,355	17		71	80	190			1,324				117,000		117,000
12-25	5.6	1,265	1,285		1,309	14		70	80	150			1,044				72,500		72,500
Totals 5	38.3					63		394	438	1,023			7,142				1,008,125		1,008,125
Sub-watershed No. 15 - Town Creek (Pennsylvania and Maryland)																			
15-3	21.8	920	935	1,011			257		282	582	8,720				874,825				874,825
15-30	7.3	1,040	1,055	1,092			191		210	195	3,720				203,000				203,000
15-35	13.7	1,024	1,040	1,122			170		187	366	5,620				652,000				652,000
Totals 3	42.8						618		679	1,143	18,060				1,729,825				1,729,825
Sub-watershed No. 19 - Little Cacapon River (West Virginia)																			
19-9	7.3	830	856		888	18		68	72	195			1,361				192,000		192,000
19-11	4.7	945	960		988	16		45	49	125			877				102,000		102,000
19-13	4.8	1,065	1,080		1,115	4		53	57	128			895				107,000		107,000
19-15A	10.4	1,120	1,147		1,186	30		71	76	278			1,939				222,250		222,250
19-16A	7.9	1,060	1,075		1,107	19		79	83	211			1,473				154,750		154,750
Totals 5	35.1					87		316	337	937			6,545				778,000		778,000
Sub-watershed No. 20 - North River (West Virginia)																			
20-18	12.4	1,260	1,273	1,282	1,327		65	87	96	330		495	2,640			29,500	245,300		274,800
20-31	5.2	1,550	1,575		1,617	12		38	43	139			970				214,000		214,000
20-33	4.6	1,425	1,450		1,473	15		41	42	123			858				175,000		175,000
20-36	9.9	1,500	1,532		1,566	24		77	83	264			1,847				189,000		189,000
20-37	7.3	1,560	1,572		1,610	17		81	87	195			1,361				147,000		147,000
20-43	5.4	1,250	1,270		1,357	68		75	85	144			1,007				254,250		254,250
Totals 6	44.8					136	65	399	436	1,195		495	8,683			29,500	1,224,500		1,254,050

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 21 - Moorefield River (West Virginia)																			
21-3A	6.4	1,060	1,095	1,165	1,182		58	74	87	171		2,568	1,908			438,525	325,475		764,000
21-4	4.2	1,115	1,171		1,237	14		31	46	112			783				214,550		214,550
21-9A	8.9	1,200	1,237		1,297	14		47	68	238			1,659				301,875		301,875
21-16A	2.3	1,213	1,248		1,294	4		17	25	61			429				184,250		184,250
21-19A	4.7	1,326	1,370		1,407	4		29	44	125			877				214,250		214,250
21-21	5.8	1,500	1,530		1,577	7		39	45	155			1,081				215,600		215,600
21-25A	2.6	1,675	1,705		1,748	6		18	27	69			485				156,875		156,875
21-30A	2.7	1,627	1,663		1,701	2		22	34	72			504				215,025		215,025
21-33	2.7	1,565	1,599		1,633	5		23	35	72			504				134,375		134,375
21-34	2.9	1,560	1,589		1,629	6		26	39	77			541				127,650		127,650
21-36A	2.3	1,548	1,568		1,603	6		27	40	61			429				91,950		91,950
21-37A	2.2	1,807	1,835		1,879	3		22	33	59			410				132,000		132,000
21-38A	3.7	1,831	1,858		1,896	8		32	48	99			690				234,150		234,150
21-39A	5.6	1,633	1,658		1,692	15		58	62	150			1,044				214,325		214,325
21-41A	5.6	1,642	1,669		1,712	9		39	59	150			1,044				159,250		159,250
21-48A	17.3	1,730	1,758	1,839	1,855		250	367	450	223		8,630	4,828			653,825	366,175		1,020,000
21-53A	2.9	2,228	2,263		2,311	5		56	67	77			541				82,050		82,050
21-54A	4.4	1,970	2,008		2,043	3		25	37	117			821				235,875		235,875
21-56A	15.2	1,968	1,987	2,058	2,077		207	258	297	271		7,570	4,312			601,925	341,075		943,000
21-59A	10.8	2,143	2,176		2,218	29		104	115	288			2,014				162,050		162,050
21-61	3.8	1,642	1,673		1,710	14		49	74	101			709				91,500		91,500
21-62	0.4	1,934	1,976		1,984	1		8	12	11			74				33,300		33,300
21-63	0.9	2,031	2,044		2,056	4		19	29	24			168				68,900		68,900
21-64	0.5	2,041	2,055		2,063	5		11	16	13			94				48,675		48,675
Totals 24	118.8					164	515	1,401	1,789	2,796		18,768	25,949			1,694,275	4,351,200		6,045,475
Sub-watershed No. 22 - Lost River (West Virginia)																			
22-2	7.3	1,645	1,673		1,713	12		64	67	195			1,361				163,000		163,000
22-16	2.8	1,830	1,846		1,884	4		23	27	75			522				69,000		69,000
22-19	8.7	1,625	1,657		1,705	20		59	64	232			1,623				395,000		395,000
22-24	10.2	1,655	1,685		1,727	17		75	82	272			1,903				225,000		225,000
22-28	7.8	1,665	1,697		1,745	18		47	50	208			1,455				335,750		335,750
22-30	8.9	1,555	1,585		1,621	20		75	79	238			1,659				201,000		201,000
22-34	10.0	1,705	1,732		1,771	24		71	76	267			1,865				275,750		275,750
22-39	4.2	1,240	1,272		1,304	8		32	37	112			783				140,000		140,000
22-45	11.9	1,640	1,661		1,687	35		145	160	318			2,219				164,250		164,250
Totals 9	71.8					158		591	642	1,917			13,390				1,968,750		1,968,750

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conser-vation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conser-vation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recre-ation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recre-ation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 23 - Cacapon River (West Virginia)																			
23-8	6.0	1,000	1,007		1,037	15		87	107	160			1,119				61,500		61,500
23-16	10.1	940	968		997	37		75	80	270			1,883				224,750		224,750
23-22	3.7	940	957		983	15		38	42	99			690				109,250		109,250
23-23	3.1	975	998		1,027	12		32	35	83			578				71,000		71,000
23-24	10.9	1,255	1,273		1,295	42		140	165	291			2,033				87,000		87,000
23-29	6.3	830	850		877	21		62	65	168			1,175				190,000		190,000
Totals 6	40.1					142		434	494	1,071			7,478				743,500		743,500
Sub-watershed No. 24 - Sleepy Creek (West Virginia)																			
24-6	5.7	695	709		727	25		93	110	152			1,063				58,625		58,625
24-12	2.1	640	653		672	13		25	28	56			392				37,725		37,725
24-13	7.6	725	750		774	26		105	116	203			1,417				122,000		122,000
24-14	5.6	722	736		757	17		100	113	150			1,044				110,375		110,375
24-18	3.0	884	894		920	14		33	35	80			560				82,725		82,725
24-19	5.8	850	860		883	20		80	90	155			1,081				78,750		78,750
24-26	15.0	920	943		974	40		152	170	401			2,797				90,200		90,200
24-27	12.4	830	849		874	52		138	147	331			2,313				126,500		126,500
Totals 8	57.2					207		726	809	1,528			10,667				706,900		706,900
Sub-watershed No. 25 - Tonoloway Creek (Pennsylvania and Maryland)																			
25-40	7.1	630	641		679	22		78	88	190			1,324				199,500		199,500
25-41	21.8	650	672	727	737		400	489	519	582	11,720		2,247		465,400		195,850		661,250
Totals 2	28.9					22	400	567	607	772	11,720		3,571		465,400		395,350		860,750
Sub-watershed No. 26 - Licking Creek (Pennsylvania and Maryland)																			
26-19	10.8	680	700		731	37		95	105	288			2,015				136,000		136,000
26-28	3.3	855	864	897			146		180	88		1,740				202,000			202,000
26-30	2.0	855	863	872	887		26	63	72	53	345	735	483		8,320	17,680	56,000		82,000
26-31	9.7	750	771		795	35		108	128	259			1,809				156,050		156,050
26-33	5.5	875	894	921	928		115	153	180	147	950	2,020	1,314		130,504	277,321	160,175		568,000
26-35	2.5	770	776		794	25		40	43	67			466				70,775		70,775
26-39	8.4	850	864		885	40		108	110	224			1,567				75,000		75,000
26-41	10.5	780	796		818	38		137	155	280			1,959				145,000		145,000
26-49	14.1	810	828		861	39		150	190	376			2,630				152,625		152,625
Totals 9	66.8					214	287	854	1,163	1,782	1,295	4,495	12,243		138,824	497,001	951,625		1,587,450

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 27 - West Branch of Conococheague Creek (Pennsylvania)																			
27-9	2.1	825	837	859			95		112	56		1,250				105,000			105,000
Total 1	2.1						95		112	56		1,250				105,000			105,000
Sub-watershed No. 28 - Conococheague Creek (Pennsylvania and Maryland)																			
28-18	1.6	556	565	593			80		103	43		960				113,625			113,625
28-19	4.0	565	579	587			35		45	107		400				125,000			125,000
28-20	1.9	525	541	565			90		100	51		1,140				90,800			90,800
28-24	7.8	595	614	654			235		290	208		4,680				390,000			390,000
28-25A	11.5	570	588	610			440		520	307		6,900				379,550			379,550
28-30	3.3	585	614	629			127		150	88		1,980				199,625			199,625
28-31	4.0	574	583	602			100		123	107		1,200				138,000			138,000
28-32	4.6	645	661	688			200		240	123		2,760				238,000			238,000
28-33	4.2	680	699	738			108		114	112		2,520				384,500			384,500
28-34	2.8	750	761	782			110		130	75		1,680				145,200			145,200
28-35	1.7	790	798	822			74		83	45		1,020				177,075			177,075
28-36	3.8	815	822	855			107		127	101	1,710	570			250,594	83,531			334,125
28-39	6.7	590	600	635			207		230	179		4,020				233,625			233,625
28-40	6.9	1,100	1,129	1,209			82		86	184		4,140				795,925			795,925
28-41	7.9	1,095	1,150	1,242			123		129	211		4,740				1,119,675			1,119,675
28-42	2.4	1,015	1,033	1,108			37		40	64		1,440				221,200			221,200
28-43	4.1	1,120	1,157	1,174			21		24	109		410				153,000			153,000
28-45	4.6	1,180	1,211	1,255			75		98	123		2,160				354,250			354,250
28-46	4.4	670	681	706			198		227	117		2,640				380,500			380,500
28-47	1.4	618	622	649			52		62	37		840				73,500			73,500
28-49A	20.3	470	489	531			560		620	542		12,180				513,750			513,750
28-51	11.2	686	703	737			355		376	299		6,720				841,125			841,125
Totals 22	121.0						3,416		3,917	3,232	1,710	65,100			250,594	7,151,456			7,402,050
Sub-watershed No. 30 - Back Creek (Virginia and West Virginia)																			
30-25A	22.4	565	596		636	51		157	166	598			4,178				237,000		237,000
30-26A	19.9	598	623	688	697		230			531		8,955	4,242			483,450	228,550		712,000
30-27A	9.5	650	677		709	28		90	98	254			1,771				170,250		170,250
30-32A	15.0	700	728		769	30		112	124	401			2,797				239,000		239,000
30-36A	16.0	732	760		794	37		137	147	427			2,984				352,750		352,750
30-45A	14.1	704	729		764	33		120	132	376			2,630				215,000		215,000
Totals 6	96.9					179	230	616	667	2,587		8,955	18,602			483,450	1,442,550		1,926,000

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 32 - Lower North Fork of Shenandoah River (Virginia)																			
32-8	6.5	825	840	880			127		137	174	1,073	2,177			110,666	221,334			332,000
32-22	7.3	1,315	1,331		1,377	18		46	49	195			1,361				96,000		96,000
32-26	8.4	850	874	891	901		50		63	224	210	630	1,783		12,162	36,488	103,350		152,000
32-36	7.2	1,345	1,354		1,386	15		106	120	192			1,343				145,000		145,000
32-42	4.7	1,140	1,152	1,167			24		27	125		470				145,000			145,000
Totals 5	34.1					33	201	152	396	910	1,283	3,277	4,487		122,828	402,822	344,350		870,000
Sub-watershed No. 33 - Upper North Fork of Shenandoah River (Virginia)																			
33-2	2.1	1,050	1,062	1,094			59			80	397	796			51,744	105,056			156,800
33-23	6.6	1,190	1,205	1,266			104			176	1,254	2,508			177,771	360,929			538,700
33-36	3.5	1,550	1,560		1,588	10		43	46	93			653				78,875		78,875
33-48A	6.2	1,525	1,550		1,578	15		40	44	166			1,156				315,000		315,000
33-49	2.1	1,290	1,302	1,328			35		40	56				389				56,625	56,625
33-52	7.7	1,720	1,736		1,767	30		77	81	206			1,436				137,500		137,500
33-59	17.0	1,475	1,502		1,538	34		135	146	454			3,170				423,200		423,200
33-63	12.4	1,800	1,840		1,880	20		68	76	331			2,313				462,950		462,950
33-64	5.4	1,390	1,410	1,449			29		31	99				690				157,600	157,600
33-68	37.8	1,060	1,087	1,150			760			1,009		21,546				1,585,000			1,585,000
Totals 10	100.8					109	987	363	464	2,670	1,651	24,850	8,728	1,079	229,515	2,050,985	1,417,525	214,225	3,912,250
Sub-watershed No. 34 - North River (Virginia)																			
34-2	1.7	1,090	1,100	1,129			100		111	45		1,261				137,500			137,500
34-7	4.7	1,190	1,202		1,236	10		83	87	125			877				71,025		71,025
34-8	1.9	1,330	1,342	1,373			92		104	51		1,410				127,325			127,325
34-14	1.7	1,270	1,275		1,293	4		45	56	45			317				33,775		33,775
34-15	11.1	1,220	1,240	1,252	1,264		520		670	296		8,236	2,366			481,750	138,250		620,000
34-20	9.0	1,259	1,273		1,294	30		145	164	240			1,679				139,600		139,600
34-26	3.8	1,290	1,310		1,324	25		69	78	101			709				92,200		92,200
34-28	4.6	1,330	1,343	1,353	1,361		176		225	123		3,413	975			171,150	48,850		220,000
34-31	5.2	1,720	1,750		1,798	14		71	81	139			970				166,600		166,600
34-36	9.6	1,968	2,002		2,048	19		58	64	256			1,791				428,950		428,950
34-40	2.8	1,315	1,326	1,366			120		136	75		2,077				225,475			225,475
34-41	4.1	1,370	1,380	1,427			88		94	110		3,042				372,050			372,050
34-43	4.9	1,470	1,496	1,541			192		200	131		3,636				393,750			393,750
34-51	2.1	1,540	1,548	1,594			54		58	56		1,558				171,300			171,300
34-52	3.6	1,400	1,420	1,457			163		187	96		2,671				296,675			296,675
34-53	2.5	1,490	1,501	1,533			114		126	67		1,855				154,450			154,450

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 34 (continued)																			
34-54	2.7	1,480	1,491	1,503			25		31	72		270				65,000			65,000
34-55	2.3	1,415	1,422	1,459			83		94	61		1,706				169,300			169,300
34-56	3.4	1,950	1,977		2,018	8		25	27	91			634				305,000		305,000
34-60	18.6	2,140	2,150		2,228	34		105	121	497			3,469				660,000		660,000
34-64	5.6	1,185	1,206		1,233	13		75	82	150			1,044				52,900		52,900
34-65	11.9	1,736	1,772	1,876	1,897		79		86	318	1,250	2,500	2,530		164,505	333,995	336,500		835,000
34-66	4.7	1,750	1,773		1,821	9		33	36	125			877				189,800		189,800
34-67	15.7	2,125	2,166	2,194	2,230		187		233	419		11,649	3,347			1,165,500	334,500		1,500,000
34-68	9.0	1,898	1,930		1,981	11		41	48	240			1,679				438,050		438,050
34-69	16.0	1,760	1,786	1,830	1,862		168		190	161		11,879	2,711			2,060,350	469,650		2,530,000
34-70	4.1	1,880	1,896		1,936	11		34	37	109			765				165,975		165,975
34-71	27.1	1,980	1,988	2,132	2,150		480		600	168		20,138	5,118			2,773,550	706,450		3,480,000
Totals 28	194.4					188	2,641	784	4,026	4,367	1,250	77,301	31,858		165,505	9,099,120	4,778,075		14,041,700
Sub-watershed No. 35 - Middle River (Virginia)																			
35-21	1.3	1,280	1,287		1,299	7		23	28	35			242				12,500		12,500
35-22	8.0	1,300	1,307	1,334	1,338		260		310	214		2,840	1,700			178,400	106,600		285,000
35-47	4.7	1,460	1,478		1,496	15		67	82	125			877				90,000		90,000
35-50	5.3	1,560	1,580		1,607	12		65	85	142			988				73,000		73,000
35-53	1.2	1,430	1,443		1,460	7		12	14	32			224				45,000		45,000
35-54	1.0	1,450	1,458		1,477	6		19	21	27			186				32,000		32,000
35-55	2.4	1,490	1,503		1,525	8		34	39	64			448				107,000		107,000
35-56	1.6	1,740	1,747		1,667	10		21	23	43			298				37,000		37,000
35-57	1.5	1,560	1,566		1,587	11		20	22	40			280				36,000		36,000
35-58	3.3	1,750	1,764		1,792	16		40	43	88			616				67,000		67,000
35-61	2.4	2,040	2,087	2,118	2,121		23		25	64				438				285,000	285,000
35-63	4.6	1,920	1,941	2,000	2,003		12		15	123				862				165,000	165,000
35-65	7.6	1,570	1,592		1,623	25		67	69	203			1,417				186,000		186,000
35-67	1.0	1,615	1,619		1,633	5		20	23	27			186				21,000		21,000
35-70	1.8	1,580	1,588		1,607	4		29	33	48			336				35,000		35,000
35-71	1.2	1,600	1,609		1,628	5		19	22	32			224				42,000		42,000
35-72	1.6	1,600	1,614		1,638	4		23	27	43			298				65,000		65,000
35-73	1.9	1,640	1,658		1,679	5		31	34	51			354				118,000		118,000
35-74	12.4	1,660	1,678		1,709	28		94	121	331			2,313				195,000		195,000
35-78	17.2	1,355	1,376		1,405	40		181	200	459			3,208				173,000		173,000
35-80	5.7	1,635	1,656		1,688	13		52	55	152			1,063				107,500		107,500
35-81	1.7	1,960	1,967		1,993	11		21	23	45			317				66,000		66,000
35-82	9.8	1,600	1,620	1,656	1,678		43		102	262	3,479		1,835		56,400		183,600		240,000

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 35 (continued)																			
35-83	7.6	1,705	1,730		1,769	21		60	63	203			1,417				235,000		235,000
35-84	9.2	1,700	1,737		1,770	17		110	128	246			1,715				185,000		185,000
35-85	19.6	1,370	1,377		1,390	175		470	570	523			3,656				240,000		240,000
Totals 26	135.6					445	338	1,478	2,177	3,622	3,479	2,840	24,198	1,300	56,400	178,400	2,458,200	450,000	3,143,000
Sub-watershed No. 36 - South River (Virginia)																			
36-1	1.4	1,140	1,155	1,186			44		47	37		595				118,000			118,000
36-2	5.0	1,400	1,425	1,495	1,514		63		82	134		2,125	1,057			169,000	84,000		253,000
36-3	3.5	1,520	1,544	1,591	1,596		90		166	93		1,487	757			181,700	90,300		272,000
36-5	1.2	1,560	1,568	1,602	1,611		33		41	32		510	259			104,100	52,900		157,000
36-6	3.9	1,252	1,257	1,288			95		140	104		1,658				168,000			168,000
36-7	5.0	1,475	1,503	1,551	1,564		81		121	134		2,125	1,045			204,350	100,650		305,000
36-10A	2.9	1,375	1,385	1,424	1,431		78		104	77		1,233	625			237,050	119,950		357,000
36-13	1.1	1,360	1,375		1,396	4		16	18	29			205				71,400		71,400
36-14	1.3	1,390	1,401		1,427	6		15	19	35			242				89,525		89,525
36-15	2.1	1,460	1,470	1,504	1,513		45		52	56	892		440		144,050		70,950		215,000
36-24A	3.7	1,800	1,830		1,869	4		33	45	99			690				155,250		155,250
36-26	1.9	1,560	1,564	1,606			60		65	51	808				216,425				216,425
36-30	2.4	1,900	1,925	1,965	1,973		27		30	64	1,020		518		135,925		69,075		205,000
36-32	2.6	1,470	1,479	1,503	1,509		85		97	69	1,240		557		82,675		37,325		120,000
36-36	3.8	1,450	1,460	1,509	1,522		60		67	101	1,615		803		143,625		71,375		215,000
36-38A	3.9	1,610	1,626	1,668	1,677		85		98	104		1,660	835			159,600	80,400		240,000
36-42	6.0	1,505	1,510	1,570	1,580		117		150	160	2,550		1,213		220,350		104,650		325,000
36-46	6.0	1,388	1,402	1,437			125		140	160	2,550				233,500				233,500
36-47	1.5	1,282	1,295	1,317			45		50	40		638				85,500			85,500
36-48	7.0	1,260	1,280	1,328			110		115	187		2,975				857,600			857,600
36-49	16.7	1,490	1,506	1,549			290		306	446	7,098				343,500				343,500
36-50	12.9	1,570	1,600	1,649			170		188	344	5,482				922,600				922,600
Totals 22	95.8					14	1,703	64	2,141	2,556	23,255	15,006	9,246		2,442,650	2,284,900	1,197,750		5,925,300
Sub-watershed No. 37 - Upper South Fork Shenandoah River (Virginia)																			
37-8	2.8	1,180	1,209	1,238			24		26	75				510				142,000	142,000
37-9	2.2	1,800	1,823	1,854			23		25	59				401				86,625	86,625
37-11	3.7	1,220	1,231		1,253	25		46	48	99			690				119,375		119,375
37-12	10.0	1,260	1,298		1,333	29		64	70	267			1,865				240,000		240,000
37-13	7.1	1,360	1,383		1,423	18		64	68	190			1,324				100,000		100,000
37-15	5.1	960	971		992	19		102	109	136			951				129,275		129,275

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 37 (continued)																			
37-16	4.2	990	999		1,013	29		82	92	112			783				117,775		117,775
37-18	3.1	1,550	1,580		1,620	6		19	21	83			578				149,625		149,625
37-19	2.7	1,340	1,352		1,368	6		22	25	72			504				65,000		65,000
37-21	1.5	1,300	1,312		1,345	6		17	20	40			280				91,000		91,000
37-22	5.8	1,110	1,127		1,158	20		52	56	155			1,081				135,000		135,000
37-36	2.8	1,520	1,542	1,608	1,620					75	56	224	575		10,745	42,980	116,275		170,000
37-42	1.4	1,475	1,481	1,504	1,509					37	125	498	263		10,125	40,500	21,375		72,000
37-50	8.9	1,220	1,250		1,295	19		58	70	238			1,659				278,350		278,350
37-51	7.8	1,025	1,073	1,115			51		54	208				1,457				243,200	243,200
Totals 15	69.1					177	98	526	684	1,846	181	722	10,553	2,368	20,870	83,480	1,563,050	571,825	2,239,225
Sub-watershed No. 38 - Smith Creek (Virginia)																			
38-6	8.0	1,235	1,252		1,275	19		135	170	214			1,492				138,250		138,250
38-8	16.8	1,170	1,187		1,218	46		175	190	448			3,134				179,300		179,300
38-9	9.2	1,050	1,066		1,099	30		74	78	246			1,715				136,725		136,725
Totals 3	34.0					95		384	438	908			6,341				454,275		454,275
Sub-watershed No. 39 - Passage Creek (Virginia)																			
39-4	4.2	1,280	1,293		1,319	15		54	59	112			783				63,225		63,225
39-7	20.5	1,000	1,050		1,074	38		172	180	547			3,824				306,600		306,600
39-9	2.5	1,340	1,357	1,385			23		26	67				456				114,950	114,950
39-10	5.3	1,340	1,363	1,405			45		51	142				991				245,500	245,500
39-11	2.3	1,200	1,206	1,231	1,238		43		53	61			491	230			30,600	15,400	46,000
Totals 5	34.8					53	111	226	369	929			5,098	1,677			400,425	375,850	776,275
Sub-watershed No. 41 - Opequon Creek (Virginia)																			
41-8	5.2	482	501		515	22		155	212	139			970				90,000		90,000
41-9	5.2	570	578		585	60		240	390	139			981				205,000		205,000
41-24	30.3	456	479	525			500		567	809		9,999				508,400			508,400
41-61	6.3	584	604	629			160		195	168		2,079				234,375			234,375
41-62	27.9	590	600	650			312		370	713		9,207				387,125			387,125
Totals 5	64.9					82	972	395	1,734	1,968		21,285	1,951			1,129,900	295,000		1,424,900

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 42 - Antietam Creek (Pennsylvania and Maryland)																			
42-26	2.9	525	531	558			125		150	77		1,560				100,775			100,775
42-27	4.7	570	588	627			140		190	125		2,820				309,175			309,175
42-32	14.7	600	633	661			521		750	392		8,820				677,800			677,800
42-38	5.7	765	816	886			200		270	152	968	1,452			175,250	262,875			438,125
42-42	2.6	680	691	734			56		67	69	624	936			110,920	166,380			277,300
42-54	9.6	610	623		646	32		102	133	256			1,791				146,000		146,000
42-57	39.9	565	584	617			360		380	1,101		11,970				1,148,000			1,148,000
42-59	29.0	618	635	681			670		710	774	6,960	10,440			570,940	856,410			1,427,350
42-60	11.4	658	680	707			220		250	300		3,420				1,090,000			1,090,000
Totals																			
9	120.5					32	2,292	102	2,900	3,246	8,552	41,418	1,791		857,110	4,611,415	146,000		5,614,525
Sub-watershed No. 43 - Shenandoah River (Virginia)																			
43-8	2.9	578	581	602			122		140	77	387	903			59,250	138,250			197,500
43-34	5.1	530	542	571			151		172	136	696	1,625			66,712	155,663			222,375
Totals																			
2	8.0						273		312	213	1,083	2,528			125,962	293,913			419,875
Sub-watershed No. 44 - Lower South Fork of Shenandoah River (Virginia)																			
44-3	1.3	570	585		602	7		21	25	35			242				44,125		44,125
44-4	1.4	800	809		839	4		19	22	37			261				77,275		77,275
44-5	7.3	900	918		953	24		62	65	195			1,361				220,000		220,000
Totals																			
3	10.0					35		102	112	267			1,864				341,400		341,400
Sub-watershed No. 45 - Hawks Bill Creek (Virginia)																			
45-4	8.7	1,030	1,051	1,101			132		140	232		3,872				396,000			396,000
45-6	2.1	1,390	1,400	1,435			35		39	56		935				205,000			205,000
45-7	1.8	830	837	864	870		66		76	48		801	390			70,550	34,450		105,000
45-8	6.1	1,100	1,112		1,158	10		74	84	163			1,138				332,000		332,000
45-9	2.4	850	863		884	9		36	40	64			448				94,275		94,275
45-10	2.3	1,080	1,100		1,115	12		28	32	61			429				102,300		102,300
45-11	2.2	1,030	1,036	1,083	1,088		58		63	59		979	460			112,200	52,800		165,000
Totals																			
7	25.6					31	291	138	474	683		6,587	2,865			783,750	615,825		1,399,575

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 46 - Goose Creek (Virginia)																			
46-10	1.9	390	405		425	8		32	38	51			354				72,000		72,000
46-11	4.0	395	411		435	9		62	71	107			746				108,300		108,300
46-13	2.9	295	305		320	14		52	68	77			541				44,750		44,750
46-19	5.6	275	282		296	20		132	165	150			1,044				92,800		92,800
46-22	5.8	385	395		418	33		119	156	155			1,075				83,450		83,450
46-26	4.9	410	425		448	12		85	100	131			904				74,750		74,750
46-28	6.9	470	476	483	494		105		250			5,382	1,287			382,500	50,000		432,500
46-39	6.9	420	449		475	18		80	90	184			1,287				151,700		151,700
46-40	3.2	615	634	677			127		140		749	1,747			106,515	248,535			355,050
46-73	8.0	400	427		449	25		110	130	214			1,492				174,875		174,875
46-78	13.2	435	452	513	518		400		520		4,118	6,178	2,827		238,340	357,510	164,150		760,000
46-81	3.8	435	446		465	10		68	80	101			709				63,475		63,475
46-85	5.8	470	488		516	17		68	75	155			1,081				77,625		77,625
46-89	12.9	305	322		343	60		168	190	344			2,406				157,800		157,800
46-92	14.8	390	419		457	30		140	160	395			2,760				173,750		173,750
Totals 15	100.6					256	632	1,116	2,233	2,064	4,867	13,307	17,226		344,855	988,545	1,489,425		2,822,825
Sub-watershed No. 47 - Catoctin Creek (Virginia)																			
47-16	2.3	600	618	643			47		53	61	360	1,434			47,200	188,800			236,000
Total 1	2.3						47		53	61	360	1,434			47,200	188,800			236,000
Sub-watershed No. 50 - Middle Monocacy River (Maryland)																			
50-24	3.5	320	332	368			150		168	93		2,730				196,500			196,500
50-30	8.3	870	900	981			144		152	222	3,884	2,590			347,550	231,700			579,250
Totals 2	11.8						294		320	315	3,884	5,320			347,550	428,200			775,750
Sub-watershed No. 51 - Toms Creek (Pennsylvania and Maryland)																			
51-2A	18.8	562	574	599			620		780	502	2,350	7,050			112,500	337,500			450,000
51-3A	4.7	870	905	956	959	11		78	84	125			877				360,000		360,000
51-5	7.4	436	456	471	475	25		210	280	198			1,380				75,000		75,000
51-6	13.6	520	557	605	608	21		75	82	363			2,537				342,000		342,000

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 51 (continued)																			
51-10	7.6	543	574	608	611	18		64	70	203			1,417				430,000		430,000
51-12	4.0	970	1,004	1,057	1,063		71		139	104		3,016	843			57,325	120,675		178,000
Totals 6	56.1					75	691	427	1,435	1,495	2,350	10,066	7,054		112,500	394,825	1,327,675		1,835,000
Sub-watershed No. 52 - Upper Monocacy River (Pennsylvania and Maryland)																			
52-3	1.6	558	565	579	580		25		36	43		1,248	340			176,850	48,150		225,000
52-4	5.8	538	550	587	596		93		150	142	332	1,328	1,130		46,925	187,700	160,375		395,000
52-8	3.4	542	558	594	597		175		230	91		2,652	723			326,550	89,450		416,000
52-16	2.2	475	486		496	18		50	70	59			410				47,000		47,000
52-18	1.4	512	516		521	4		9	12	37			261				45,000		45,000
52-19	1.4	505	509		521	9		42	47	37			261				47,500		47,500
52-20	1.5	503	507		521	7		42	56	40			280				59,000		59,000
52-21	4.4	920	966		1,000	11		44	52	117			821				235,000		235,000
52-24A	9.4	630	652	712	718		325		465	251	1,466	5,866	2,005		119,320	477,280	163,400		760,000
52-25	1.1	590	603		621	4		8	10	29			205				90,500		90,500
52-26	1.9	675	687	722	726		92		116	51		1,482	413			209,575	58,425		268,000
52-30	6.6	437	762	487	495		142		245	176		2,518	1,408			275,625	154,375		430,000
52-32	3.7	440	451	489	494		165		230	99		2,887	962			345,000	115,000		460,000
52-34A	8.2	445	463	504	509		340		500	219		6,396	1,744			353,700	96,300		450,000
52-37	2.2	462	467	495			144		165			1,716				430,600			430,600
52-38A	4.2	499	502	523	526		260		360	112		3,276	908			207,500	57,500		265,000
52-39	3.3	500	511	538	539		243		475	88		2,574	710			212,475	58,525		271,000
52-40	1.6	502	506	530	533		100		180	43		1,248	379			143,425	43,575		187,000
52-43	17.9	535	549	587	592		510		780	478		13,962	3,817			494,550	135,450		630,000
Totals 19	81.8					53	2,614	195	4,179	2,112	1,798	47,153	16,777		166,245	3,840,830	1,704,525		5,711,600
Sub-watershed No. 53 - Big and Little Pipe Creeks (Maryland)																			
53-7	7.9	498	511	516	534		45		132	211		4,164	1,687			17,125	142,875		160,000
53-12	5.1	555	574	586	606		61		82	136		1,022	1,094			49,150	210,850		260,000
53-17	3.5	598	612		633	11		56	66	93			653				110,000		110,000
53-19	15.8	605	627		642	12		228	250	422			2,946				590,000		590,000
53-24	5.4	665	680	719			122		135	144		2,700				240,000			240,000
53-28	3.8	598	604	653	658		120		152	101		2,280	800			255,300	89,700		345,000
53-28A	2.8	532	546		563	10		40	50	75			522				92,500		92,500
53-31A	10.7	475	488	524	527		450		620	286		6,420	2,275			387,600	139,900		527,500
53-45	2.6	455	463		475	11		51	68	69			485				64,000		64,000
53-46A	10.6	495	508	557	559		450		565	283		8,268	2,261			657,050	179,950		837,000

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 53 (continued)																			
53-49	1.2	445	457		480		76		92	32	234	702			26,481	79,444			105,925
53-52A	8.4	463	478		499	33		95	110	224			1,567				181,625		181,625
53-54	2.4	503	517	549	553		121	127	165	64	468	1,404	517		60,762	182,288	66,950		310,000
53-55	3.7	442	450		464	21		70	90	99			690				136,750		136,750
Totals 14	83.9					98	1,445	667	2,577	2,239	702	26,960	15,497		87,243	1,867,957	2,005,100		3,960,300
Sub-watershed No. 58 - Broad Run (Virginia)																			
58-6	3.0	215	223	235	245		130		159	80		2,340	637			171,250	80,000		251,250
58-9	4.7	260	277	329	337		106		125	125		3,666	1,006			392,500	107,500		500,000
58-14	7.9	260	265	298	300		235		300	211		6,162	1,687			145,200	154,800		300,000
Totals 3	15.6						471		584	416		12,168	3,330			708,950	342,300		1,051,250
Sub-watershed No. 59 - Bull Run (Virginia)																			
59-2	3.0	245	251	286	290		110		137	80	594	1,206	633		41,514	84,286	44,200		170,000
59-7	6.0	160	170	208	213		52		86	160	198	402	1,314		18,075	36,700	120,225		175,000
59-9	7.2	211	215	253	259		140		171	192	1,425	2,895	1,547		121,440	246,560	132,000		500,000
59-11	6.4	242	250	281	286		190		212	171	1,056	2,144	1,370		26,433	53,667	219,900		300,000
59-13	13.4	233	242	259	262		220		265	358	2,211	4,489	2,866		154,360	287,640	168,000		610,000
59-19	2.0	175	182		197	10		33	47	53			373				46,100		46,100
59-31	3.3	205	215	250	256		90		119	88	544	1,106	707		42,735	86,765	55,500		185,000
59-34	2.3	228	240		255	12		42	61	61			429				86,525		86,525
59-37	2.0	260	274	303	309		52		87	53	198	402	431		23,050	46,800	50,150		120,000
59-39	10.6	270	282	325	335		195		215	283	1,049	2,131	2,265		79,018	135,432	145,550		360,000
59-41	10.0	265	275	308	313		105		117	267	1,650	3,350	2,139		65,835	133,665	85,500		285,000
59-46	24.9	198	205	255	263		450		520	665	3,287	6,673	5,312		107,580	218,420	174,000		500,000
59-47	12.2	223	230	248	251		490		570	257	3,140	6,375	2,603		146,363	297,162	121,475		565,000
Totals 13	103.3					22	2,094	75	2,607	2,688	15,352	31,173	21,989		826,403	1,627,097	1,449,125		3,902,625
Sub-watershed No. 60 - Occoquon Creek (Virginia)																			
60-16	12.0	244	250	298	301		450		509	320	936	8,424	2,560		32,970	296,730	90,300		420,000
60-25	2.7	190	198	206	214		32		46	72	27	243	573		3,200	28,800	68,000		100,000
60-27	2.3	220	224		237	15		27	34	61			429				40,000		40,000
60-30	3.5	228	252		277	6		14	19	93			653				140,000		140,000
60-35	9.4	450	459	486	501		180		212	251	376	3,380	2,000		31,017	279,158	164,825		475,000

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conser-vation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conser-vation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recre-ation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recre-ation	Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 60 (continued)																			
60-38	7.6	460	482		509	27		53	61	203			1,417				225,000		225,000
60-39	15.8	495	503	524	546		220		265	422	632	5,688	3,381		26,690	240,210	143,100		410,000
60-42	11.9	155	162	181	189		97		118	318	476	4,284	2,543		30,317	272,858	161,825		465,000
60-52	4.8	173	181		195	42		78	91	128			895				97,000		97,000
60-57	8.1	230	240		254	46		82	97	216			1,511				62,000		62,000
60-63A	5.6	233	242		258	42		78	91	150			1,044				116,000		116,000
60-68A	2.7	262	276		300	10		26	34	72			504				130,000		130,000
60-70	1.8	295	300		311	32		57	76	48			336				40,000		40,000
60-72	7.0	337	354		382	17		43	51	187			1,305				120,000		120,000
60-73	19.6	370	380	419	425		440		515	513	748	6,732	4,180		27,605	248,445	153,950		430,000
60-79	8.8	368	379		386	60		94	114	235			1,641				50,000		50,000
Totals 16	123.6					297	1,419	552	2,333	3,289	3,195	28,751	24,972		151,799	1,366,201	1,802,000		3,320,000
Sub-watershed No. 68 - Seneca Creek (Maryland)																			
68-19	3.1	280	292		313	17		46	50	83			578				66,300		66,300
68-20	3.0	295	304		321	13		56	68	80			560				84,225		84,225
68-21	4.8	315	323		342	17		88	105	128			895				153,725		153,725
68-23	4.3	345	360		375	19		82	107	115			802				100,100		100,100
68-25	7.7	355	369		389	28		126	150	206			1,436				145,050		145,050
68-28	3.5	400	421		441	12		54	66	93			653				78,575		78,575
68-29	2.5	505	522		541	8		42	53	67			466				45,400		45,400
68-31	3.3	470	484		506	11		50	58	88			616				51,250		51,250
68-33	3.9	450	463		485	14		63	70	104			727				91,450		91,450
68-35	10.1	275	285		309	22		165	200	270			1,883				123,125		123,125
Totals 10	46.2					161		772	927	1,234			8,616				939,200		939,200
Sub-watershed No. 69 - Rock Creek (Maryland)																			
69-13	12.8	300	319	323	352		74		259	342			2,395	600			14,772	7,100	21,872
69-14	12.2	270	286	298	333		54		194	294			2,395	795			14,773	7,675	22,448
Totals 2	25.0						128		453	636			4,790	1,395			29,545	14,775	44,320
Sub-watershed No. 71 - St. Mary's River (Maryland)																			
71-4	2.5	15	23		38	14		38	55	67			466				57,300		57,300
71-5	6.8	39	45		59	61		145	162	182			1,268				59,500		59,500
71-6	8.2	61	70		83	53		210	260	219			1,529				140,250		140,250

Table 21 (cont.) - Upstream Structural Measures, Potomac River Basin

Site no.	Drainage area	Elevation: Flood plain	Elevation: Top sediment pool	Elevation: Top conservation pool	Elevation: Spillway crest	Surface Area: Sediment pool	Surface Area: Conservation pool	Surface Area: Flood prev. pool	Surface Area: Maximum pool	Total Storage: Sediment	Total Storage: Water supply	Total Storage: Water quality control	Total Storage: Flood prev.	Total Storage: Recreation	First Cost: Water supply	First Cost: Water quality control	First Cost: Flood prev.	First Cost: Recreation	First Cost: Total cost
	(sq.mi.)					(acres)	(acres)	(acres)	(acres)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Sub-watershed No. 71 (continued)																			
71-70	2.7	30	33		43	20		115	155	72			504				32,000		32,000
Totals 4	20.2					148		508	632	540			3,767				289,050		289,050
Sub-watershed No. 74 - Zekiah Swamp - Gilbert Run (Maryland)																			
74-22A	8.2	60	75		94	77		103	119	480			2,890				393,725		393,725
74-26	2.7	81	93		104	23		91	137	158			942				126,550		126,550
74-30A	4.3	106	119		133	40		160	210	265			1,290				182,825		182,825
Totals 3	15.2					140		354	466	903			5,122				703,100		703,100

Basin Totals

Drainage area (square miles) - 2,777.4
Surface area sediment pool (acres) - 4,743
Surface area conservation pool (acres) - 25,398
Surface area flood prevention pool (acres) - 19,416
Surface area maximum pool (acres) - 51,297
Sediment storage (acre-feet) - 71,002
Water supply storage (acre-feet) - 106,211
Water quality control storage (acre-feet) - 471,509
Flood prevention storage (acre-feet) - 425,516
Recreation storage (acre-feet) - 7,819
First cost water supply storage (dollars) 8,748,478
First cost water quality control storage (dollars) 42,340,172
First cost flood prevention storage (dollars) - 51,684,900
First cost recreational storage (dollars) 1,981,275

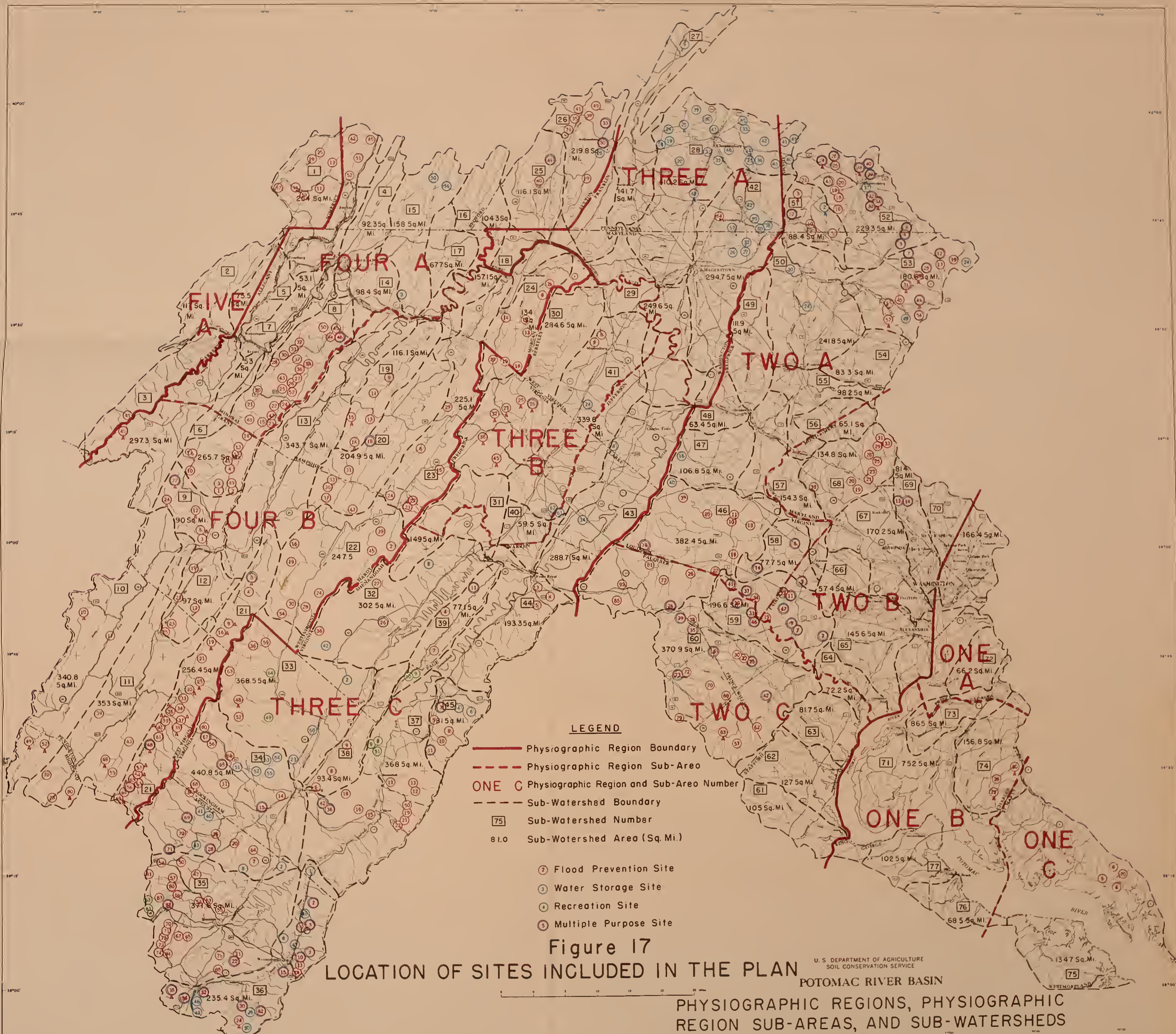


Figure 17
LOCATION OF SITES INCLUDED IN THE PLAN

PHYSIOGRAPHIC REGIONS, PHYSIOGRAPHIC REGION SUB-AREAS, AND SUB-WATERSHEDS